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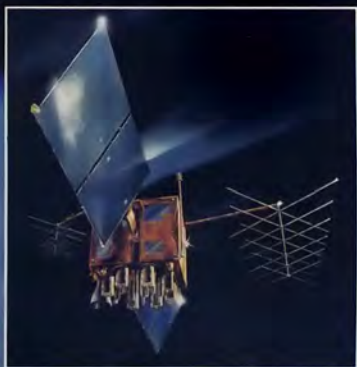
The Magazine of Space Exploration

November/December 1990



# SPACE PATROL

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EYES AND EARS  
IN ORBIT**



**PLUS!**

**SEVEN WONDERS  
OF THE SOLAR  
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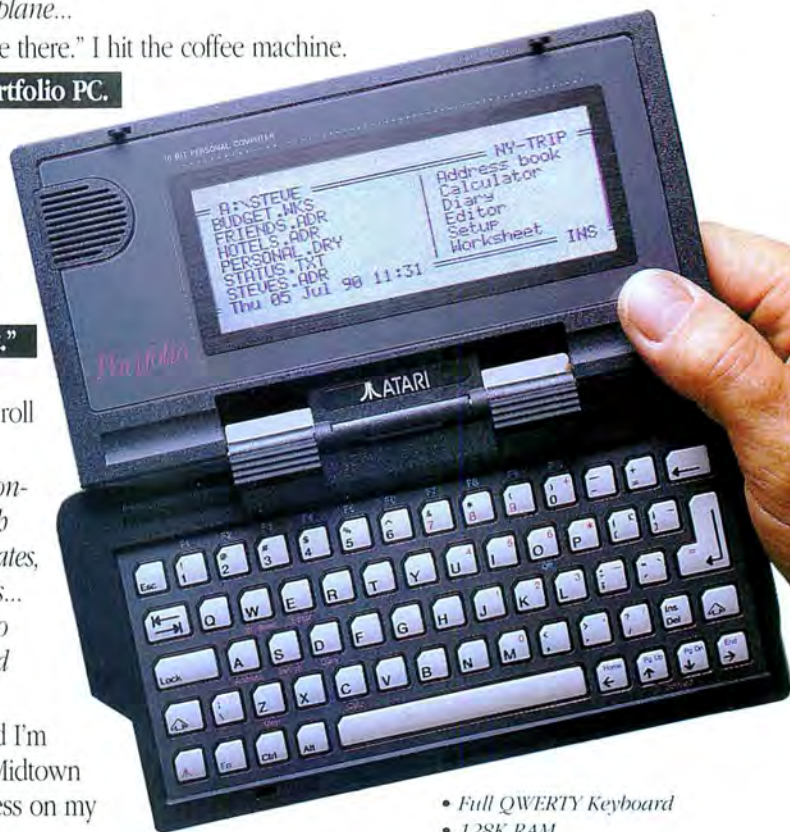
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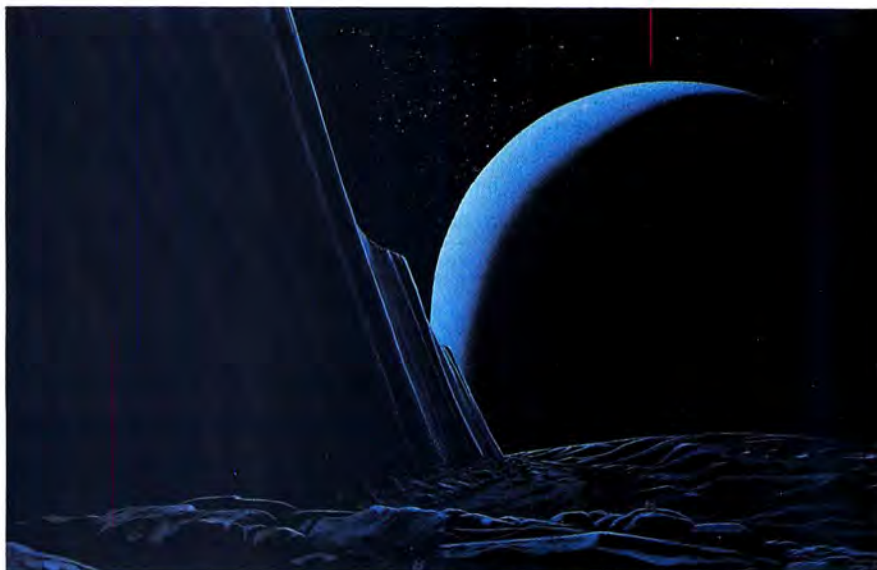
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Proxima Centauri-the nearest star

edition of 950

by David A. Hardy

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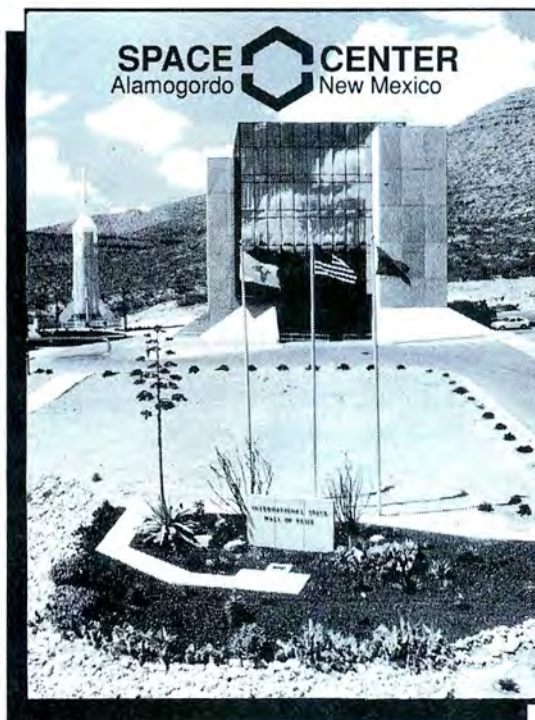
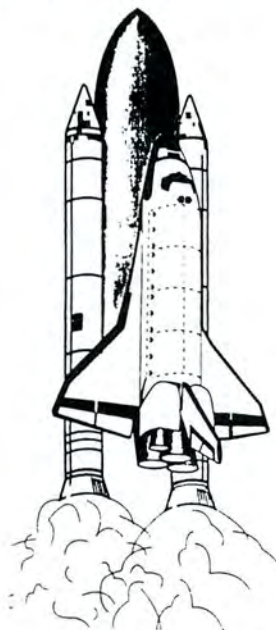
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# Letters



## Commercial Boosters

**W**hy are most recent articles about America's nascent commercial launch services so gloomy? Your "10,000 Toyotas" (July/August 1990) is the latest one that seems to declare the industry in trouble just as it is getting started.

The primary challenge for American launch companies now is to break into the marketplace and secure a market share. How to do this? By establishing a track record of successful launches. Ariespace has already done this, and as the decade progresses, its market share will probably decline as "foreign competition" gains a foothold.

Also, a word on subsidies. They might help make our boosters more competitive, but they would also make their operators slaves to Washington's political winds. A brief reading of NASA's history should establish the perils in that.

*Michael J. Gallagher  
Cortland, New York*

## Pitching Hubble

**A**m I missing something? The cover of the July/August issue headlines "Hubble's First Snapshots of the Universe!" I turned to the index to find what pages these pictures were on. Nothing listed, so I started from the front of the magazine, page by page, found the "Mission File" for STS-31, but no Hubble snapshots of the Universe.

Finally, on the last page, after all the classifieds, I found *one* picture taken by the Hubble Space Telescope. Pictures, plural? Universe?

*Donald R. Scott  
Springfield, Massachusetts*

## Committee Fever

**E**nough already! I see that yet another committee/task force/panel has been established to "examine the future of space policy." These advisory bodies are becoming a cottage industry. There are the National Research Council's committees, NASA's own in-house seers, various congressional subcommittees and now the Space Council's newest task force chaired by Norman Augustine [see page 48]. These panels invariably draw their members from the same sources: former astronauts, aerospace contractors (preferably individuals who were active during the "glory days" of Apollo), past NASA officials and a few scientists. Some names turn up on more than one committee. Under these circumstances, it's questionable whether any sort of fresh insights or definitive action will emerge.

NASA is an agency talking to itself. Instead of dredging up the same experts to consider the same questions and come to the same conclusions (i.e., increased funding, better leadership, a call for some bold plan of exploration reminiscent of the Moon shot) NASA would do well to stack its next committee with people from outside the space field. It would then stand a better chance of getting the innovative ideas it professes to crave.

Anyone who has followed space policy and agency management in recent years knows what is needed for reform. But it's always easier to talk about reform than to actually do anything. Instead of funding these many policy committees, NASA should use the money to do the obvious: Pay government salaries that are competitive with those of private industry. Strengthen in-house quality control to oversee the work of the numerous contractors and subcontractors. Establish a clear line of management that will eliminate excess bureaucracy and end the rivalry

among regional space centers that shredded any semblance of project cooperation in the mid-1980s.

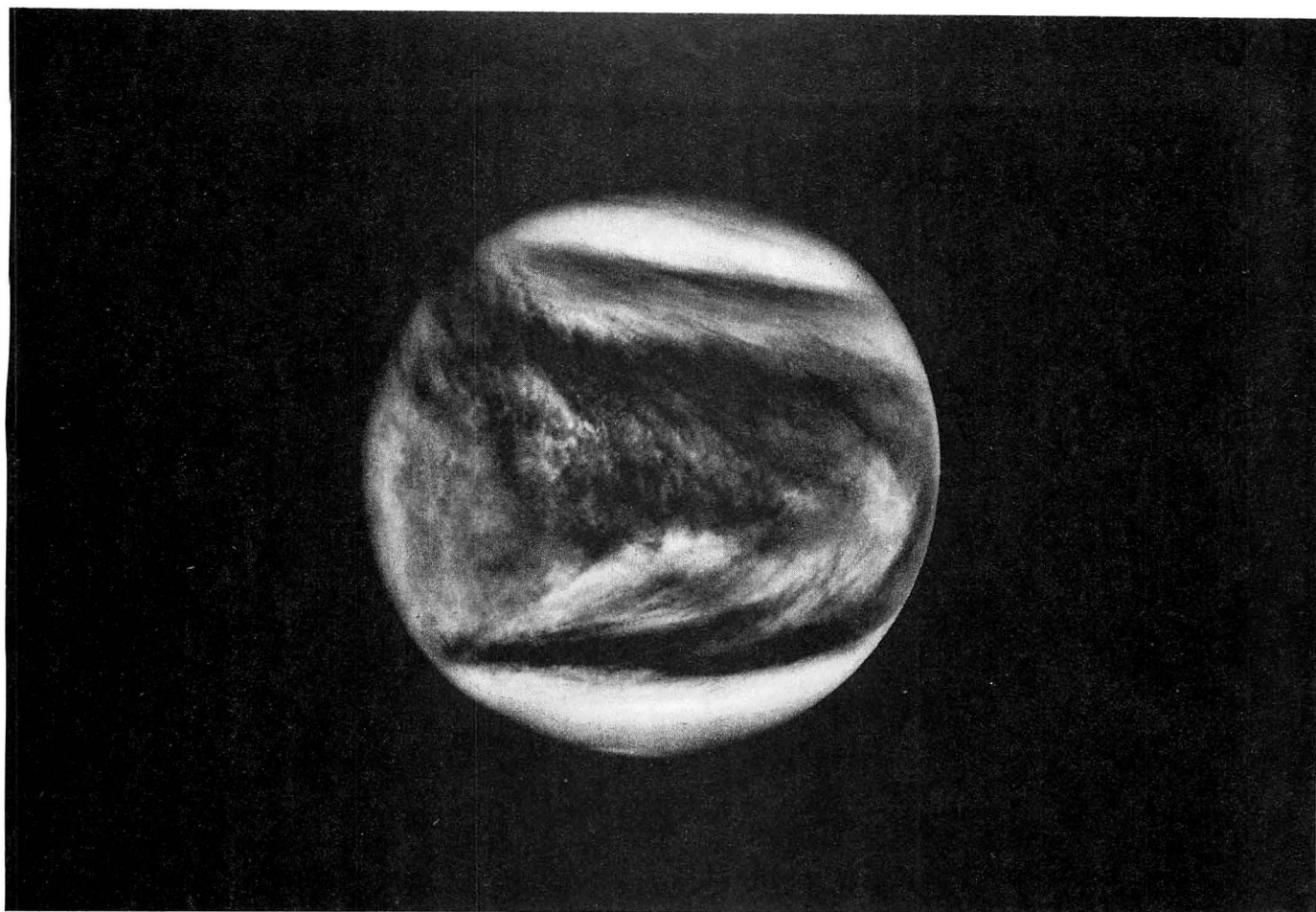
Above all, be straight with the public and Congress, and be uncompromising in demanding adequate support. The unforgiving environment of space is no place for engineering designs based on economy instead of function. Another in-flight accident like the Challenger disaster will always be possible. But NASA should make sure the next accident will not be one "waiting to happen"—that is, another disaster that gave plenty of warning beforehand. Congress, meanwhile, should understand that its funding squeeze was a principal reason behind NASA "overselling" the space shuttle and the space station as well.

Still, NASA is an agency worth supporting, and periodic demands to scrap it and start over are misplaced. Every organization hits a plateau in its fervor and goal-setting abilities. It is wiser to fix problems with NASA now rather than to start over and face the same situation in a new agency a few years down the road. But a succession of advisory ventures just escalates administrative costs and drains resources that could otherwise be used to actually implement some of the countless recommendations.

It is true that we came to the stars on the shoulders of giants. But I wonder how many of those giants spent their time replicating committee reports.

*Ann Saccomano  
Washington, D.C.*

*FINAL FRONTIER welcomes your letters. Send them c/o Letters to the Editor, FINAL FRONTIER, P.O. Box 11519, Washington, D.C. 20008. Please type your correspondence and limit the length to 150 words.*



# Our Sister's Revealing The Family Secrets.

On August 16th, after a 15-month, 948-million-mile journey, NASA's Magellan spacecraft took its first look at the surface of our sister planet, Venus.

And what we've already learned is remarkable. By using a special imaging radar that can "see" through the thick clouds covering the planet, Magellan has revealed a surface of lava flows and faults geologically similar to places here on Earth.

It's an important step toward unravelling one of the great mysteries of the universe—why two planets, similar in size and location, evolved so radically differently. What caused the Venusian atmosphere to assume its devastating "greenhouse effect," and what can it mean for our own environmental future on Earth? It's time for Venus to tell her story.

**MARTIN MARIETTA**

6801 ROCKLEDGE DRIVE, BETHESDA, MARYLAND 20817

# The Observatory

## Earth to Verne!

*It took space engineers more than a century to overtake one novelist with a wild imagination. ■ By Ron Miller*

**O**ne hundred and twenty-five years ago this year, the French writer Jules Verne published the third of his many popular novels. Known to English readers as *From the Earth to the Moon*, Verne's account of an amazing journey into outer space proved to be not only his most influential work, but arguably one of the most important novels ever written.

A great many fanciful accounts of travel to the Moon and to other planets had been written before Verne's *De la Terre à la Lune*, with propulsion methods ranging from migrating geese to violent sneezes, balloons and antigravity. But Verne, the ex-stockbroker who would later be called the father of modern science fiction, was the first to consider the problem of spaceflight on strictly mathematical and technological terms. In doing so, he managed to shape modern rocketry as well, making it perhaps the first modern science with roots in a fictional work.

Verne intended much of the book to be an affectionate but perceptive satire of American "go-get-it-iveness." Nevertheless, he also wanted to show exactly how a flight to the Moon might be conducted—using only the technology available in 1865, and without inventing new materials or introducing any imaginary science. This concern for detail led him to invent the giant cannon used to launch his capsule, a decision for which he has been taken to task by critics ever since.

The author had little choice, however, since rocketry in his day had produced nothing but unreliable solid-propellant projectiles weighing a few dozen pounds and traveling a few thousand yards.



**Jules Verne, as portrayed in the original 1865 edition of *De la Terre à la Lune*.**

Readers at the time would have laughed at the idea of using such rockets for a lunar launch. There is abundant evidence that Verne knew full well the limitations and dangers inherent in his Moon gun. Ironically, guns as a means of space transportation are back in vogue 125 years after Verne's crew of Barbicane, Nicholl and Ardan was shot toward the Moon (see "Have Guns, Will Travel," January 1990).

Beyond this, the novel's "predictions" and coincidences are occasionally uncanny. Verne has his launch take place from central Florida, only a hundred miles or so from Cape Canaveral (he chose the site for the same reason NASA did: its proximity to the equator). He envisioned the use of a three-man spacecraft whose weight, dimensions and main construction material resemble those of the Apollo capsule. Despite his reliance on the launch cannon, Verne also foresaw the value of rockets as effective propulsion devices in the vacuum of space—he used them in his story to break

the fall of the capsule onto the lunar surface.

In addition, he portrayed the "merchandising" of the space flight and the ticker-tape parades that followed the successful splashdown—which happened to be in the Pacific Ocean, where the projectile was retrieved by a ship from the U.S. Navy, just as the Apollo 11 capsule was in 1969.

Verne—who in other books anticipated submarines, air travel and television—was apparently the first writer of any kind to realize the escape velocity needed to leave Earth. The novel's careful mathematics were performed by Verne's cousin, a professor of mathematics at the Sorbonne. It was this unprecedented attention to detail that inspired such youthful readers as Russia's Konstantin Tsiolkovski, Transylvania's Hermann Oberth and many other pioneers of rocketry—including Robert Goddard and Wernher von Braun—to seriously pursue the problem of space flight.

"Possibly the first seeds of the idea," wrote Tsiolkovski, "were sown by that great fantastic author Jules Verne—he directed my thinking." Oberth claimed that "I always had in mind the rockets of Jules Verne" as he struggled to build his own during the 1920s and 1930s.

Without Verne's inspiration, we might not be as far along as we are today in the exploration of space. Astronomer Robert Richardson agreed: "There can be no doubt that Jules Verne's trip to the Moon, with all its faults, has exerted a powerful effect on human thought in preparing our minds for this greatest of adventures."

*Ron Miller's article "The Seven Wonders of the Solar System" appears in this issue.*

## The next bold journey

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A new world lies 40 million miles from earth. It is time to start the journey. It is time to open the universe to all humanity.



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# Review

## *The SETI Factor*

By Frank White

Walker and Company

250 pages, \$19.95

By Ed Regis

**T**he late physicist Richard Feynman used to say when it came to understanding why the basic quantum particles acted the way they did, *nobody knows anything*. "I don't understand it," he once said. "Nobody does."

Exactly the same might be said about the existence and nature of extraterrestrial intelligence, as well as the possible consequences of contact. Nobody knows whether extraterrestrials exist, what they'd be like if they did, or what it would mean to life on Earth if contact with them were

ever established. This lack of knowledge hasn't stopped people from writing books on the subject, though, and Frank White's *The SETI Factor* is the latest in a long line.

White—who has subtitled his book "How the Search for Extraterrestrial Intelligence Is Changing Our View of the Universe and Ourselves"—acquaints us with some of the most recent thinking about extraterrestrials. We learn about the so-called Anthropic Cosmological Principle, according to which the entire universe evolved expressly to permit the human race, and the human race alone, to exist. If the principle is true, then SETI—the Search for Extraterrestrial Intelligence—is seen to be a misguided project.

On the more optimistic side, we learn about "Contact" conferences, the next one of which will be held in Phoenix in March 1991. These public forums, according to

the author, provide "the opportunity to prepare for contact." Contact groups divide up into a Human Team and an Alien Team, and are challenged to invent possible contact scenarios, giving participants the chance to experience the Joy of Contact.

We also learn about the NASA SETI Microwave Observing Project—a massive computerized radio search for extraterrestrial signals that's scheduled to begin in 1992, pending congressional approval.

White himself is a SETI optimist—nay, an enthusiast. He's sure we'll eventually hear from the extraterrestrials, and that this will be one of the most momentous things that ever happened to the human race. In fact, he thinks we ought to start preparing for this encounter *now*.

"Preparing for contact should be seen as a global process and a global priority," he says. He advocates broad-based educational programs about SETI; argues that "a major international SETI media conference should be held as soon as possible"; and calls for the creation of interdisciplinary research teams, committees, task forces, even institutes—all of them dedicated to getting us "ready for SETI." Contact, you'd think, is just around the corner.

Alas, the author's enthusiasm is not so well grounded as these ringing calls to action might suggest. One virtue of White's book is that although he's an unbridled optimist himself, he dishes out the bad along with the good. For example, he realistically examines the famous "Drake Equation," formulated by astronomer Frank Drake in 1961 as a way of estimating how many technologically developed civilizations there are in the Milky Way galaxy. As White shows, correct solutions to the equation range

anywhere from *one* such civilization (us) to *one billion*. He acknowledges that it's entirely possible, and fully consistent with all known scientific facts, that we may be utterly alone in the cosmos.

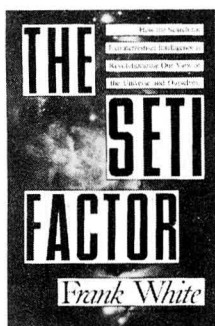
He also acknowledges that even if there *are* other intelligent species out there, we might never learn of their existence: They might be outside our "search space," or we might be using the wrong search techniques. Or, they might be *within* our search space but choose not to communicate with us. White realizes that these possibilities are in complete agreement with known science—and yet he urges immediate action to welcome the Martians onto our shores. Why? Why the major international media conferences, the committees, the SETI institutes and the rest?

The answer seems to be that these days SETI is a Politically Correct Fantasy. Who could fail to be stirred by the thought of "Others" out there beaming all sorts of good stuff our way—the *Encyclopedia Galactica* and everything else.

More than that, thinking about ETs serves to unify us into "One World." The SETI fantasy, in other words, is an antidote to egocentrism, anthropocentrism, and all those other vestiges of politically retrograde thinking. And that's why we have to "get ready for SETI" *now*; good politics demands it.

No indeed, *nobody knows anything* about extraterrestrials. But if you'd like to join the fantasy, Frank White's book is an up-to-date place to begin.

*Ed Regis edited the 1985 anthology Extraterrestrials: Science and Alien Intelligence, and is the author of Great Mambo Chicken and the Transhuman Condition: Science Slightly Over the Edge, published this year.*





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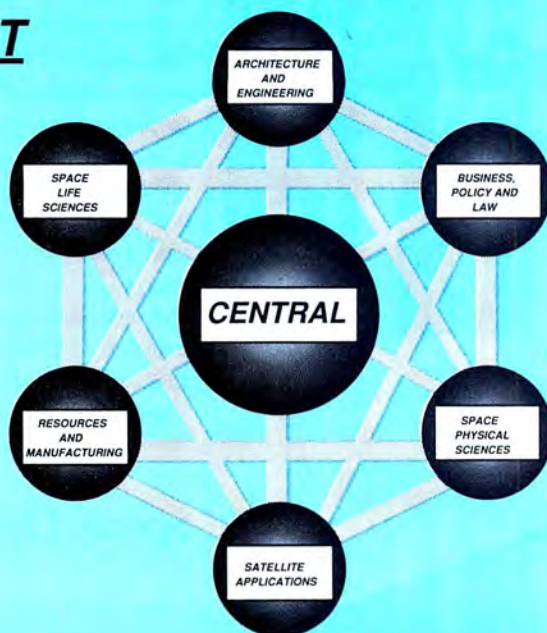


tional diversity which are the hallmarks of the ISU program. ISU has benefited from participation and support of leading world academic institutions. The Massachusetts Institute of Technology (MIT) in the United States hosted the inaugural ISU'88. Université Louis Pasteur in France accommodated ISU'89, and York University in Canada hosted ISU'90. The Soviet Union and Japan will host the program in 1991 and 1992, respectively. The ISU Board of Directors' recent approval of summer sessions in 1993, 1994, and 1995 will enable ISU to continue globalizing its academic operations -- and challenging its past successes.



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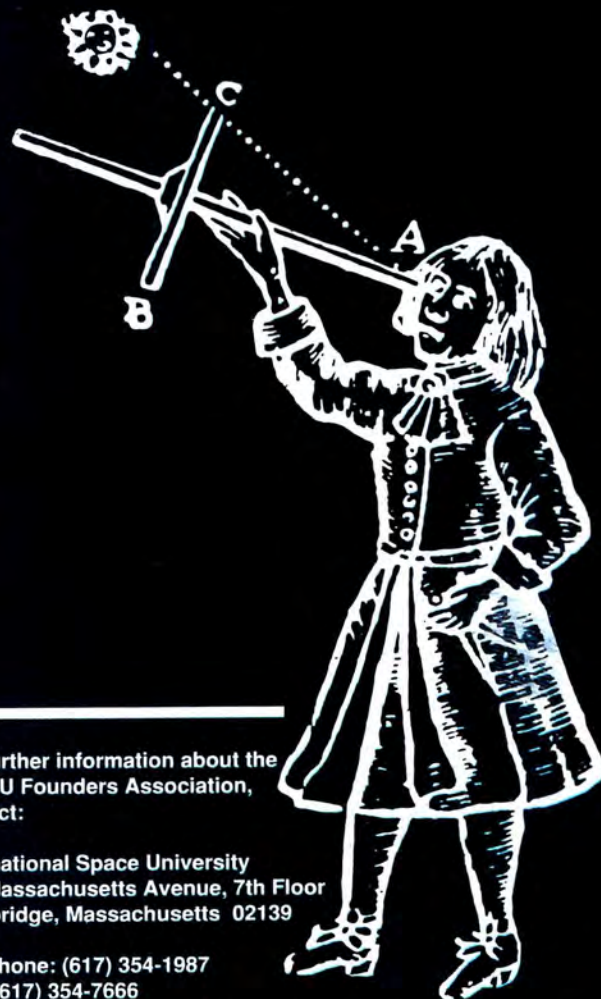
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## Catch the Wave

Surfing across deep space at Mach 100, you and your "waverider" spacecraft could make it to Pluto—three billion miles away—in four years flat.

Radical, dude.

The waverider "will open up missions that have been impossible before," says Mark Lewis, an aerospace engineer at the University of Maryland. "It will revolutionize interplanetary transportation," agrees James Randolph, a mission designer at NASA's Jet Propulsion Laboratory.

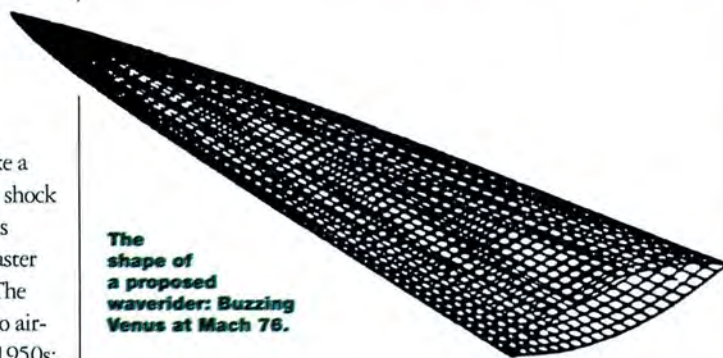
Lewis explains that a waverider flies "kind of like a surfboard," buoyed by the shock waves it creates as it travels through the atmosphere faster than the speed of sound. The concept has been known to airplane engineers since the 1950s; a full-scale prototype of a waverider bomber was even built in 1964.

What excites Lewis and Randolph is the idea of applying this aerodynamic principle to planetary missions. Probes like Voyager and Galileo routinely use "gravity assists" to whip around large planets such as Jupiter in order to pick up energy and change direction. The closer they fly to the planet, the faster they get whipped around.

Because of the spacecraft's remarkably high lift-to-drag ratio, a long, thin waverider

could actually fly close enough to a planet to dip into its atmosphere without being slowed too much by drag. A waverider could buzz Venus, for example, and use

# NOTES FROM EARTH



The shape of a proposed waverider: Buzzing Venus at Mach 76.

lifting force to thrust itself back out of the atmosphere and on toward its destination. The gravity assist would actually be enhanced.

With waveriders, interplanetary flight times could be cut dramatically. As an example, it would take 12 years to get to Pluto using current gravity assist techniques. A waverider launched on a rocket or dispatched from a space station could swing by Mars and make it to Pluto in as little as a third of that time. Nine months, max, for a trip to the Sun with a detour through the atmosphere of Venus. On Randolph's drawing board is a solar probe he hopes will be launched on a waverider soon after the turn of the century.

One major engineering hurdle still to be overcome is the frictional heating that would occur when a spacecraft zipping through the vacuum comes into contact with a planetary atmosphere. The current lack of a

material that can withstand temperatures hotter than 5,000 degrees Fahrenheit is one reason why waveriders are still on paper and not in space. There are ideas for insulating such a spacecraft—liquid hydrogen cooling "veins," leading edges made of diamond—but so far no solutions.

Nevertheless, the idea fascinates mission designers like Randolph. "You can do things that have never been thought of in the wildest dreams of the orbital mechanics community," he says.

One of those things—the ability to change orbits—apparently has captured the attention of the Pentagon.

"Once you stick a space shuttle in an orbital plane, a few degrees of change [in inclination from the equator] is the limit, and even that requires enormous amounts of fuel," Lewis says. A waverider is versatile by comparison.

"Fall back into the atmosphere, re-enter slightly, use the lifting force to fly through any

angle you want. The military is very interested in that," Lewis says.

So far, though, only NASA is supporting the research with money—less than \$1 million in six years. University of Maryland scientists are using supercomputers at the Jet Propulsion Laboratory to work out aerodynamic formulas for a waverider, and have produced two models undergoing testing in wind tunnels at NASA's Langley Research Center in Hampton, Virginia.

—Beth Dickey

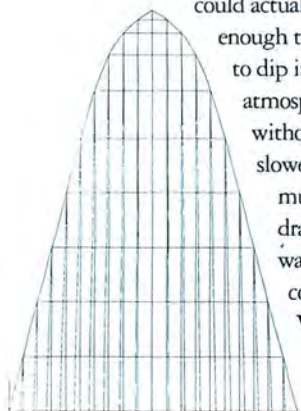
## Spacey Opinions

One out of two Americans who answered a recent poll at Florida's EPCOT Center claimed they don't know much about the U.S. space program. The same percentage also said it would be more exciting to visit another solar system or space station Freedom than the Moon or Mars.

So concludes a Roper survey of 4,845 adults who volunteered their opinions on the American space effort during one of the regular opinion polls conducted at Walt Disney World's EPCOT Center. Among the findings:

Of those asked, 48 percent—including more than half the women who responded—said they know "not too much" about the space program. Of the men, 53 percent claimed to be fairly knowledgeable. Only 6 percent of those polled said they know "a great deal."

The respondents split on whether NASA is moving fast enough to explore the Solar System. The poll showed 44 percent saying yes, with 45 percent saying no. Those who thought NASA was moving "too slowly" were predominantly men or people between





18 and 34 years old. Generally, younger people and men seem most gung-ho about American exploits beyond Earth.

By comparison, older people and women appear to be the least enthralled. Asked about government spending on space, 35 percent of those polled expressed satisfaction. But 26 percent—including 31 percent of the women and 37 percent of those 65 or older—said the United States is spending “too much.” Twenty-nine percent said the nation is spending “too little.”

Nearly 60 percent—more men than women and more younger people than older people—think the space program has paid for itself through scientific discoveries and technology spinoffs.

Two-thirds want the study of Earth's environment to be the space program's top priority over the next 20 years. Thirteen percent said the main goal should be a lunar base, and only nine percent said it should be a manned mission to Mars.

A majority of the American visitors, 61 percent, want the U.S. to speed up construction of space station Freedom.

Fifty-six percent said NASA should emphasize manned and unmanned exploration equally. But a quarter of the men, compared to 20 percent of the women, prefer manned space-flight.

A combined 59 percent would book a space vacation to another

solar system or space station Freedom. Men prefer interstellar travel and older people prefer low Earth orbit. Of those polled, 18 percent would visit a Martian settlement and only 9 percent would go to the Moon.

When the same questions were put to 1,885 of Epcot's international visitors, a similar percentage—about half—claimed to be informed about the U.S. space program, but slightly more of the foreign respondents said they believe the United States is too aggressive in its space exploits.

A nearly equal number—65 percent—said they want “more study of the Earth's environment” to be the U.S. space program's primary goal in the next 20 years.

Like their American counterparts, they chose another solar system over the space station as the most exciting travel destination.

—Beth Dickey

## Smarter Than the Average Robot

George isn't the sort of guy you'd like to meet on a blind date. Even though he's probably the smartest student at Georgia Tech, his teachers say he doesn't have a lot of common sense. At least not yet. He's only 45 inches tall. He weighs 400 pounds. He has 24 eyes. Sounds

like a ramblin' wreck.

He's actually an autonomous mobile robot.

Researchers at the Georgia Institute of Technology in Atlanta have programmed George with models of the hormonal systems that control “flight-or-fight” decisions in mammals. They claim to have shown that machines are capable of making “instinctive” survival decisions.

The researchers think that animal behavior will provide the blueprint for a new generation of robots that could someday navigate hazardous waste sites, nuclear power plants, coal mines, deep oceans—even distant planets—without remote-control assistance.

Robots can be instilled with the common sense to seek shade when the sun is too hot or take shortcuts when they're low on fuel, according to Ronald Arkin, a Georgia Tech computer scientist.

“The goal is to make these machines more self-reliant, to make them survive situations that are potentially dangerous, to make them more responsive to changing conditions,” Arkin explains.

NASA has labeled autonomous decision-making a must for future planetary rovers, for two reasons: Robots can go where humans can't, and the lag time for commands relayed from Earth makes teleoperation impractical.

“The intent is for these vehi-

cles to be capable of operating on their own with just a very general set of directions,” says David B. Lavery, manager of NASA's planetary rover program.

Engineers at NASA's Jet Propulsion Laboratory (JPL) in Pasadena spent the summer testing a six-wheeled, three-bodied, semi-autonomous prototype. The rover uses sophisticated sensors and a database to detect obstacles, then plots a specific path over and around them while navigating a general, pre-programmed course of six miles or more through rugged terrain.

A brainier robot, with six legs that can step over crevices and boulders, was unveiled at the Carnegie Mellon University Robotics Institute in Pittsburgh last May. Developed for NASA, the machine uses laser sensors to create a three-dimensional topographical map, which it studies to decide where to walk and what objects to sample.

The missing link in this robotic evolution, according to NASA, is perception. Arkin thinks George—with 24 ultrasonic distance sensors, a black-and-white imaging camera and a modicum of animal instinct—may have found it.

The Georgia Tech robot, programmed with a collection of about 15 different behaviors, has moved beyond simple obstacle avoidance to begin “opening its eyes in an unfamiliar area and exploring, rather

JPL's new rover going its own way.



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# NOTES FROM EARTH

than having a preconceived knowledge of the world," Arkin says. "We're dealing with robotics in dynamic, unstructured worlds."

—Beth Dickey

## Talking Trash

In yet another effort to make flying in space less like camping out, NASA engineers have installed a trash compactor on the space shuttle.

The machine can mash a bag of garbage down to a fourth its normal size, leaving welcome elbow room for astronauts who—apparently delirious with cabin fever—have been overheard describing the winged spaceship as "nothing but a cramped little camper."

NASA wants to make the trash compactor a permanent appliance on extended-duration shuttle flights scheduled to begin in 1992. Lockheed Science and Engineering Corporation built the machine with a spinoff for recreational vehicles in mind.

How better to test the experimental compactor than with a crew of seven, cooped up for ten days inside orbiter Columbia?

"The idea is to see if this is a good design, and to get the crew's comment on how easy it is to operate," explains Gary Coen, mission control chief for this fall's ASTRO-1 Spacelab flight.

"Regardless of what we ever put in space, we're always going to have a confined area for relatively large numbers of people," Coen says. "You want to be able

to optimize their accommodations."

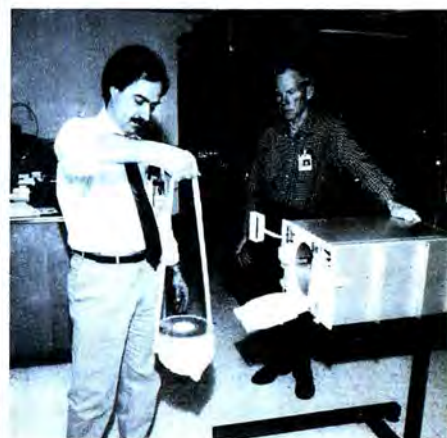
That's a delicate way of pointing out that the garbage won't all fit under the floorboards like it does now. According to NASA, each astronaut bags a cubic half-foot of trash a day. The garbage is stuffed through an eight-inch hole in the mid-deck floor into a compartment called "Volume F."

By current estimates, 56 cubic feet of trash will collect during a 16-day extended-duration flight. The 48-pound compactor, stowed in a mid-deck locker, could reduce that to 14 cubic feet. A manually operated piston inside the chamber mashes the garbage with a force of about 60 pounds per square inch. The special polypropylene bags are then sealed with charcoal filters and lids to trap odors, fluids and bacteria.

To test the compactor, engineers crushed everything from computer paper and plastic food containers to soda cans and cat food. After a year of experiments, it came out smelling like a rose.

"It's easy to mess with your garbage in the back yard because the atmosphere is open and you have a lot more leeway," Coen explains, but dealing with floating garbage in zero-g is another story.

—Beth Dickey



**Testing the shuttle's trash masher.**

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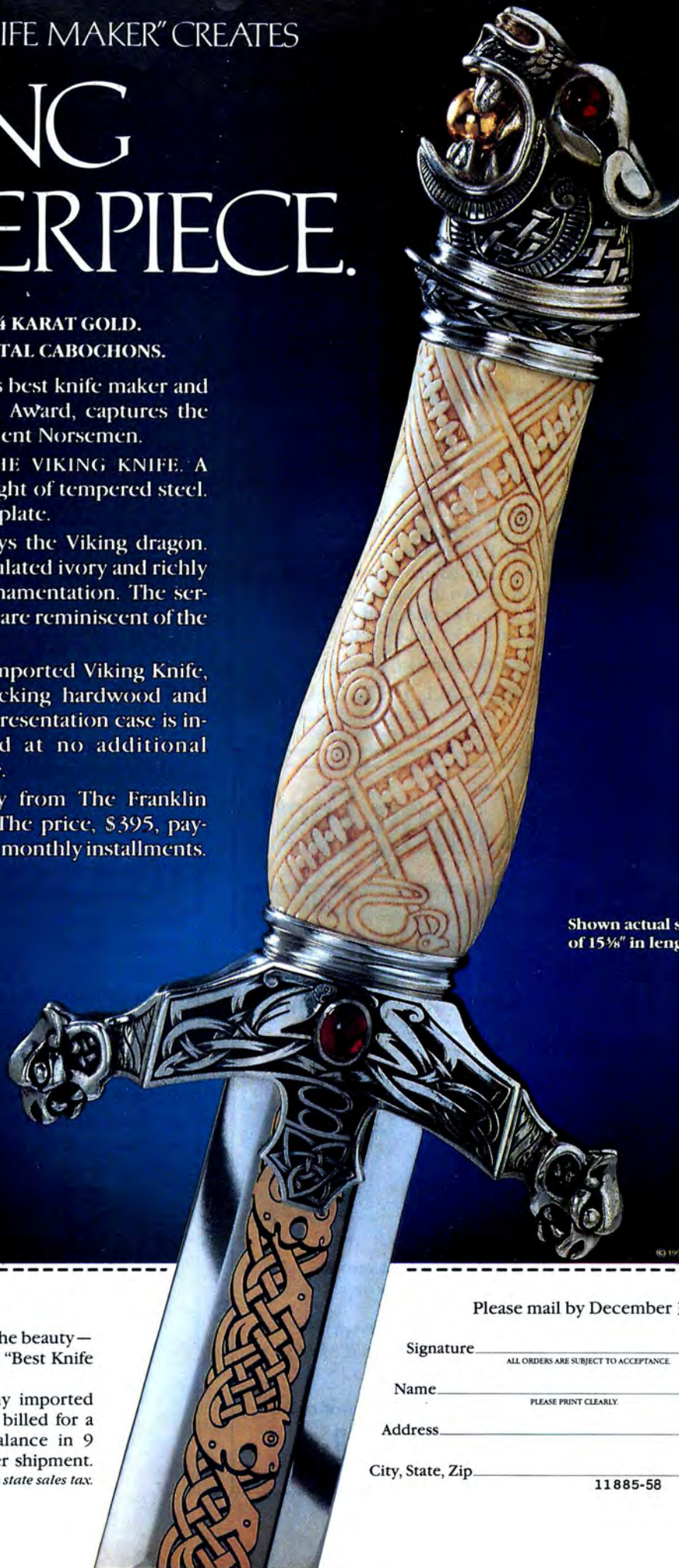
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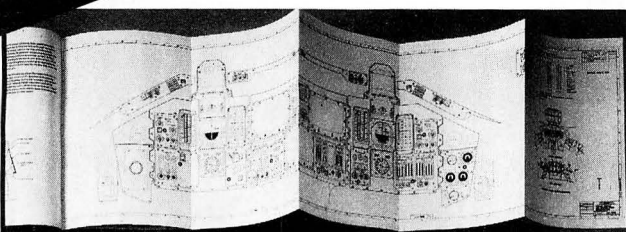
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## NOTES FROM EARTH

### Mr. Acronym

There's one difficulty to being an astronaut that may not occur to the eager wannabee: mastering NASA-speak, an alphabet soup of thousands of abbreviations and acronyms that can stump even the veterans.

Here's a recent snippet of dialogue from onboard space shuttle Columbia:

"We've already had AOS IOS. We expect LOS TDRS East in about four minutes. Probably pick you up on the west side AOS TDRS West at 22:12. However, we will continue with IOS for another six minutes and 40 seconds until LOS."

Jack Martin would have no problem translating that for the befuddled layperson. The astronaut was merely saying: "We will continue to hear you through the Indian Ocean station for six minutes and forty seconds. In four minutes, we'll lose your transmission through the eastern satellite, but will pick you up later through the western satellite."

Having spent the past 10 years as NASA's unofficial Acronym Czar, it's no surprise that Martin is a whiz at translating the agency's

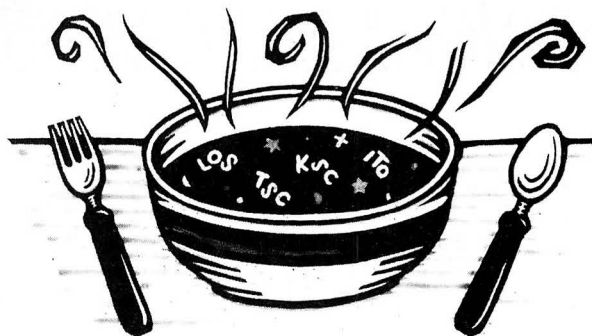
estimated 16,000 abbreviations. For those who are pernickety about titles, his office was known as the SP-OPI-KSC (Shuttle Program, Office Program Integration, Kennedy Space Center).

NASA-speak was created by engineers who sought shorthand ways to describe complicated concepts, Martin says. But once the engineers got their creative juices flowing, there seemed no stopping them—and no stopping the confusion created by their acronyms.

Documenting these myriad acronyms fell to Martin, whose office created a popular glossary for NASA-speak. It saw two printings and was made available to all NASA offices nationwide. But even Czars do not reign forever.

"The Scientific and Technical Branch of NASA in Washington decided to move the task of [creating a glossary of NASA-speak] elsewhere," Martin says. "So we turned all our data over to NASA headquarters." Now deposed, Martin works at Cape Canaveral at the ITO as an ADPM (Translation: he's an automatic data processing manager in the Information Technology Office). And the name of NASA's new authority on acronyms? "NASA Publication 1059 Revised," Martin replies, with just a trace of sadness.

—Joseph Baneth Allen





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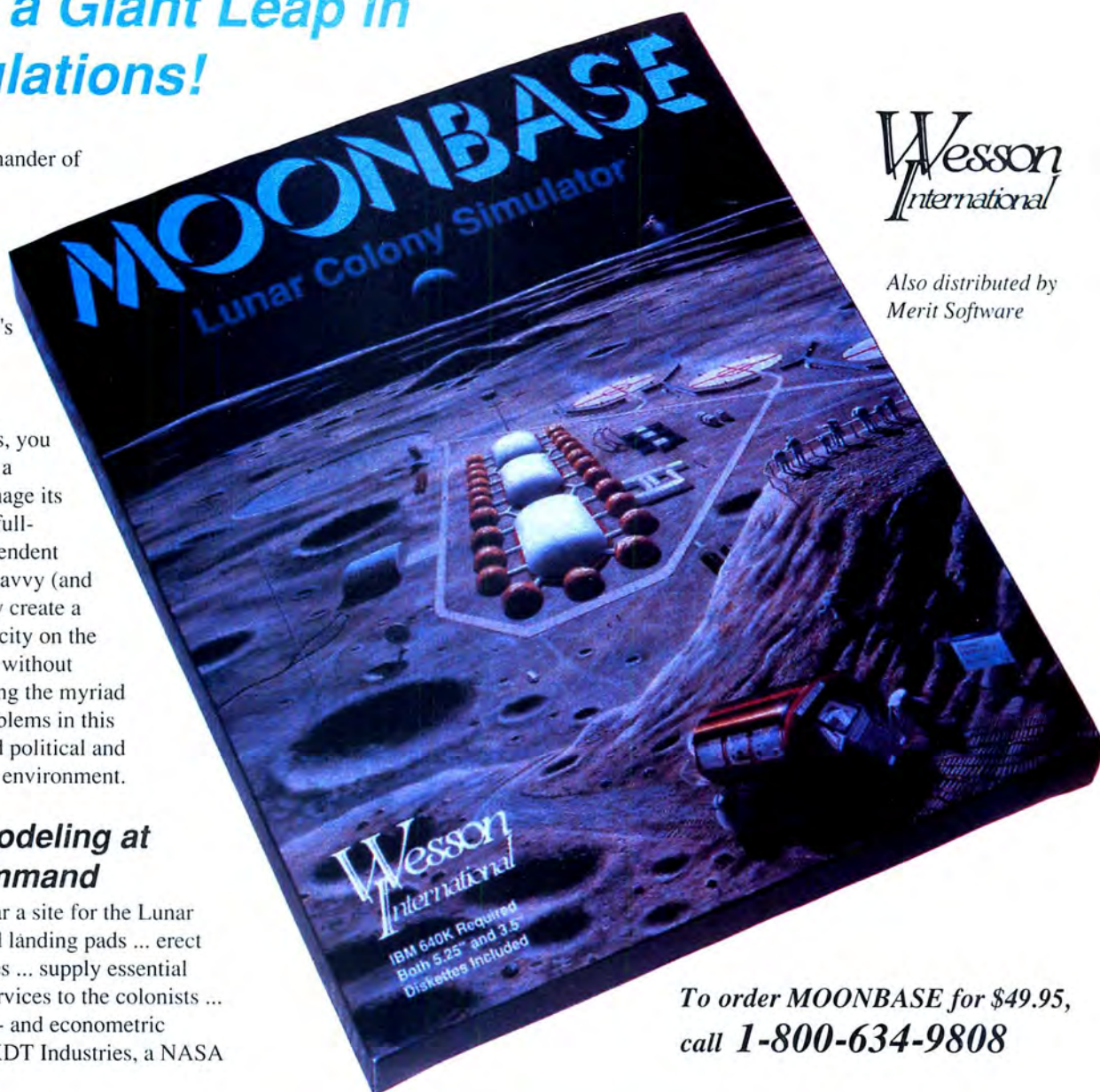
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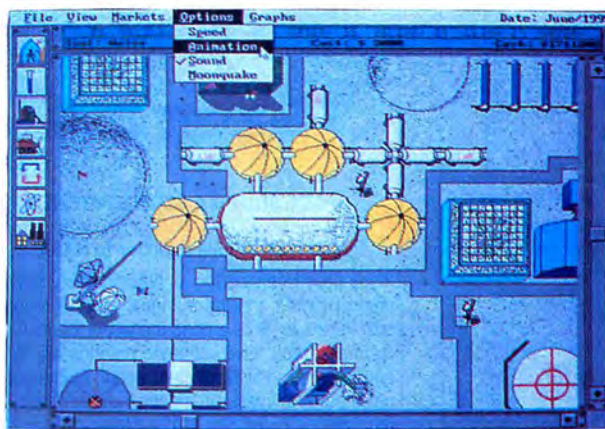
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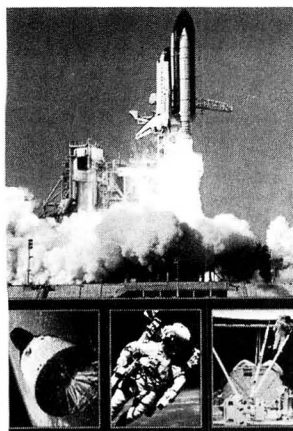


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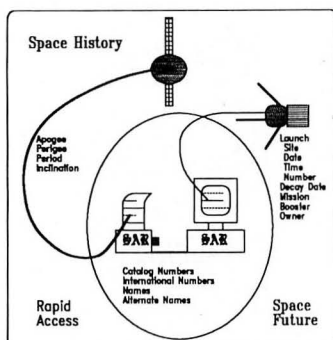
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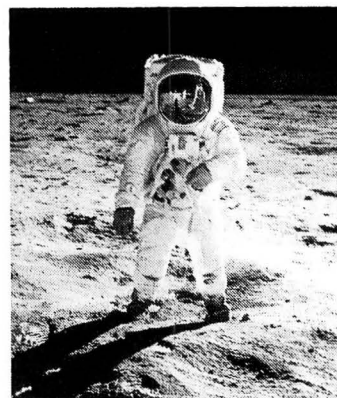
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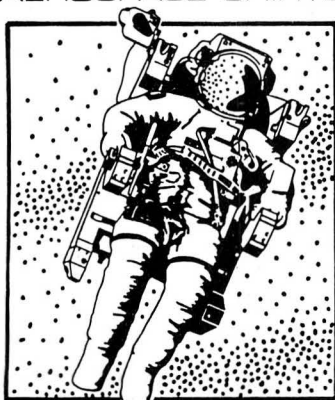


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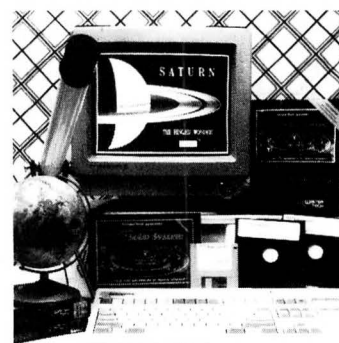


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*A Travel Guide for the Interstellar Tourist*

Of The Solar System

After diligently saving your *shlopars* for years, you and your family can finally afford the vacation you've been dreaming about. The children—boys, girls and *flidits*—twist their tentacles into complex geometric shapes and begin to radiate far into the ultraviolet in their excitement. “Mommy, Daddy, Flideen!” they cry in chorus, “Are we really going to Sol?” “Yes, we are, at last!” you answer, smiling as the tykes begin to disintegrate in their happiness. “All right, children, pick up your pieces and start packing. The *Mathenaut* solves its equation tomorrow morning and we don't want it to curve without us!” “How far is Sol from Alpha Centauri, Daddy?” “More than four light years, Peedner Prime, now no more questions!” “Well, darling,” asks your wife/flideen simultaneously, since they're in a state of fusion at the moment, “just what can we afford to do?” “We've been through the travel brochures and it looks like we've got to limit ourselves to seven stops.” “Seven! Is that all?” they reply, congealing in disappointment. “It's better than nothing. Besides, the Rastopopovars could only make one stop, remember?” “That's true, and at a comet so far from Sol they had to have the star pointed out to them.” “Right! We can only visit seven places, but it can be any seven we want!” “The Rastopopovars will eat *dridli* in envy!” “With their eyes shut! All right, then, let's go through the choices and decide what we most want to see.” “It's not going to be easy.”



**Our Solar System** contains nine planets, scores of moons and thousands of planetoids and comets—most of which have their own unique and fascinating features. Choosing only seven sites in the Solar System to visit *wouldn't* be easy. What kind of criteria should determine our selection? Aesthetic? Scientific? Historic?

We started asking around.

Planetary scientist Carl Sagan thinks that life on Earth would include all seven wonders rolled into one. But while Sagan is amazed by the Earth's "wide variety of biochemical [and] morphological...wonders," he may be biased. After all, to paraphrase a point he made elsewhere, if our Alpha Centauran family were sufficiently alien, all terrestrial organisms might seem pretty much alike. Chemically, all earthly life shares a common heritage; there are more fundamental similarities between you and your pet cat than there are differences. Our Alpha Centauran family might have a hard time telling a human from a chrysanthemum. What's more, for all we know life may be a common occurrence throughout the universe. Its presence on Earth might strike interstellar visitors as little more than a curiosity.

But in its own Solar System, Earth is unique in possessing both abundant life and vast quantities of liquid water. Astronaut and National Space Society president Charlie Walker would choose two of the seven wonders to represent this wealth and variety: Australia's Great Barrier Reef (a choice seconded by Apollo 11 astronaut Mike Collins) and a tropical forest.

Would human cities and structures prove fascinating to extraterrestrials? Perhaps, in the same way that we find coral reefs or termite mounds beautiful or curious. Walker would include the city of Paris on his wish list, while Collins is even more specific, narrowing one of his choices down to a single structure: the Washington Cathedral. International Space University co-founder Todd Hawley chose a site of human activity rather than a specific artifact: Apollo 11's Tranquility Base.

To an approaching visitor, the hands-down winner among roadside attractions would have to be the neon truck-stop sign of our Solar System: Saturn and its magical, mystical rings. Planetary rings may be a fairly common phenomenon; they show up four times in our Solar System alone. But there's no reason to suppose that rings like these are anything but rare. Advertisements for our Solar System in Alpha Centauran travel brochures would need to say little more than "see Earth's weird zoo and Saturn's rings!"

Beyond these two "must-see" spectacles, the list becomes a matter of personal preference. Several of the friends I polled opted for the volcanoes of Jupiter's moon Io as a clear choice, and I certainly agree. A close runner-up would be Jupiter's Great Red Spot ("Of course," added science fiction author Hal Clement). A cyclonic storm large enough to swallow a planet the size of Earth would be an awe-inspiring sight when seen

from close up.

Other contenders include Olympus Mons on Mars—the largest known volcano and the largest mountain of any kind in the Solar System. Like that other Martian marvel, Mariner Valley, Olympus Mons derives its impressiveness from its sheer size. The amazing cliffs of Miranda—one of Uranus's five tiny moons—are an often overlooked wonder, as is Saturn's "Death Star" moon, Mimas, with its giant eye. (When the first Voyager picture of Mimas was slowly unveiled, line by line, on a television screen at the Jet Propulsion Lab in 1980, there was a hushed silence before an awed voice asked—only half facetiously—"Is that the engine?")

The double-planet system of Pluto-Charon was another suggestion, but except for the thrill of seeing an over-large moon in the sky, the "wonder" is mostly an intellectual one. A double asteroid like Hektor might be more exciting. A visitor to Hektor could experience the thrill of having a whole world hanging so close overhead that it would be possible to jump from one to the other.

There's a serious side to this speculation, as well: It's not too early to consider protecting some of these remarkable places. Any talk of mining various moons or terraforming other planets, however speculative, should consider plans for setting aside certain areas forever. It would be an easy thing to do now, perhaps via the International Astronomical Union. Our descendants could one day be as grateful to us as we are to the Congress that voted to make Yellowstone—a remote and nearly inaccessible region of the western American wilderness—the planet's first national park back in 1872.

### SEVEN WONDERS OF THE SOLAR SYSTEM:

- ❶ THE RINGS OF SATURN
- ❷ MARINER VALLEY ON MARS
- ❸ EARTH'S OCEANS AND LIFE
- ❹ JUPITER'S GREAT RED SPOT
- ❺ THE VOLCANOES OF IO
- ❻ THE GREAT WALL OF MIRANDA
- ❼ HEKTOR

#### THE RUNNERS-UP:

8. OLYMPUS MONS (MARS)
9. THE STRAIGHT WALL (EARTH'S MOON)
10. CALORIS BASIN (MERCURY)
11. HALLEY'S COMET

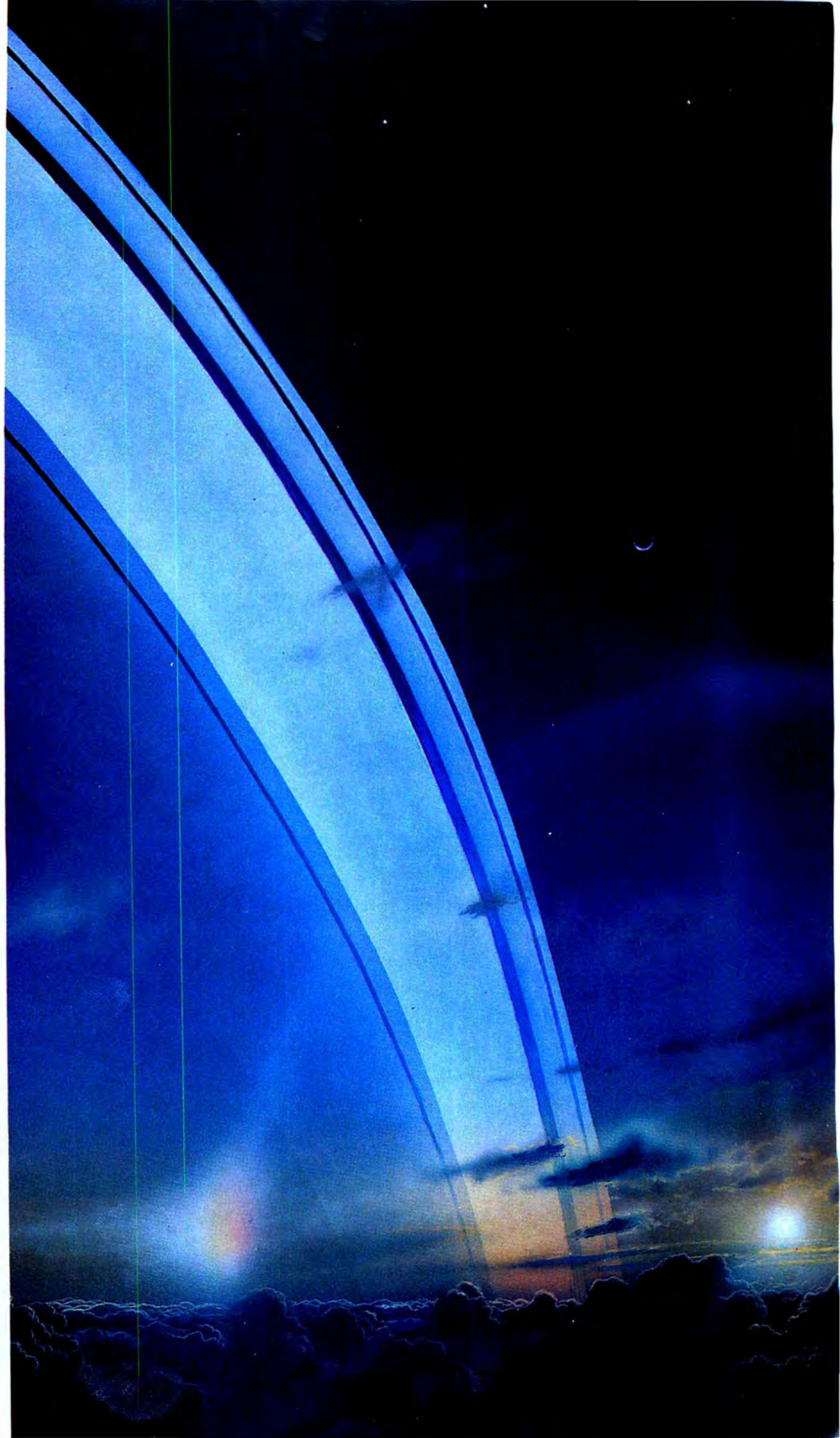
*Ron Miller is a well-known space artist and writer. His books include The Grand Tour, Out of the Cradle and Cycles of Fire.*

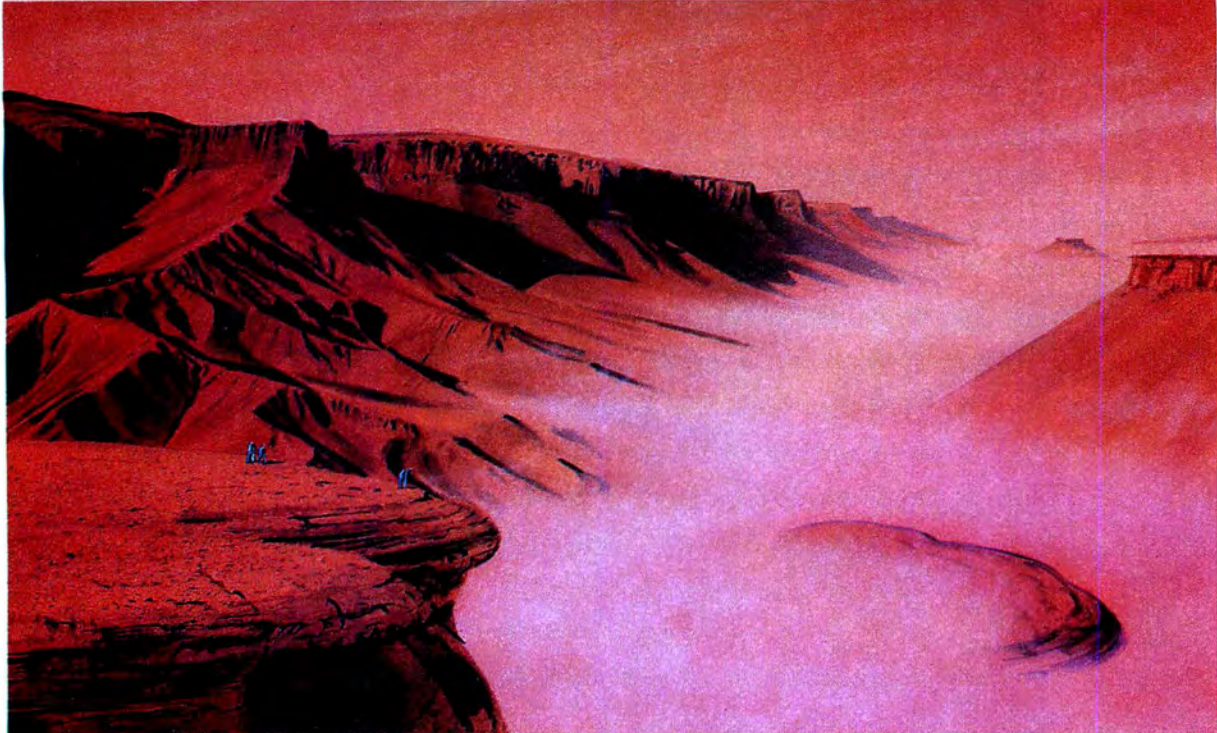
## *1. The Rings of Saturn*

Arching over the cloud tops like a silver rainbow, Saturn's rings must be the most magical sight in our Solar System. Their appearance would vary with the observer's location, the time of day and the season. In this view, we hover above Saturn's cloud deck, watching the sunset during the Saturnian equinox. We are at 15 degrees south latitude, looking almost due west. Where the rings dip behind the horizon they are tinted pink for the same reason the setting Sun and Moon often appear reddened to us. The giant shadow of Saturn itself will soon sweep over the rings like the hand of a vast clock, moving more than twice as fast as the hour hand of an actual clock on Earth.

The distant Sun—almost a tenth the diameter it appears in Earth's sky—is surrounded by a faint halo of light refracted from ice crystals high in Saturn's atmosphere. The crystals are also responsible for the bright "sundog" near the center of the picture.

The nearest visible edge of the ring system is about 13,000 miles away, though the rings probably extend down to the atmosphere. The outermost visible ring is 72,000 miles away—a third the distance between the Earth and Moon. In fact, our Moon could easily slip through the large gap in the rings known as Cassini's Division.





## 2. *Mariner Valley*

Mariner Valley, named for the Mariner 9 spacecraft that discovered it in 1971, is an enormous scar in the Martian surface, as much as five miles deep and 150 miles across. Also known as Valles Marineris, the canyon is longer than the United States is wide. Only Earth's 3,000-mile mid-Atlantic rift valley can rival it in size and form. The Grand Canyon in Arizona would hardly stand out among the many steep-walled tributary canyons that create the vast Mariner Valley complex.

Like the great rift valleys on Earth, Mariner Valley is the result of large-scale faulting of the planet's crust—not water erosion as in the case of the Grand Canyon. Perhaps the Atlantic Ocean basin in its youth once resembled this great Martian chasm.

The valley stretches east and west almost exactly along the Martian equator, and there are many places where it is so wide that someone standing on the canyon floor would not be able to see its walls. Here we view a portion of the valley from its rim, perhaps three miles above the fog-enshrouded floor.

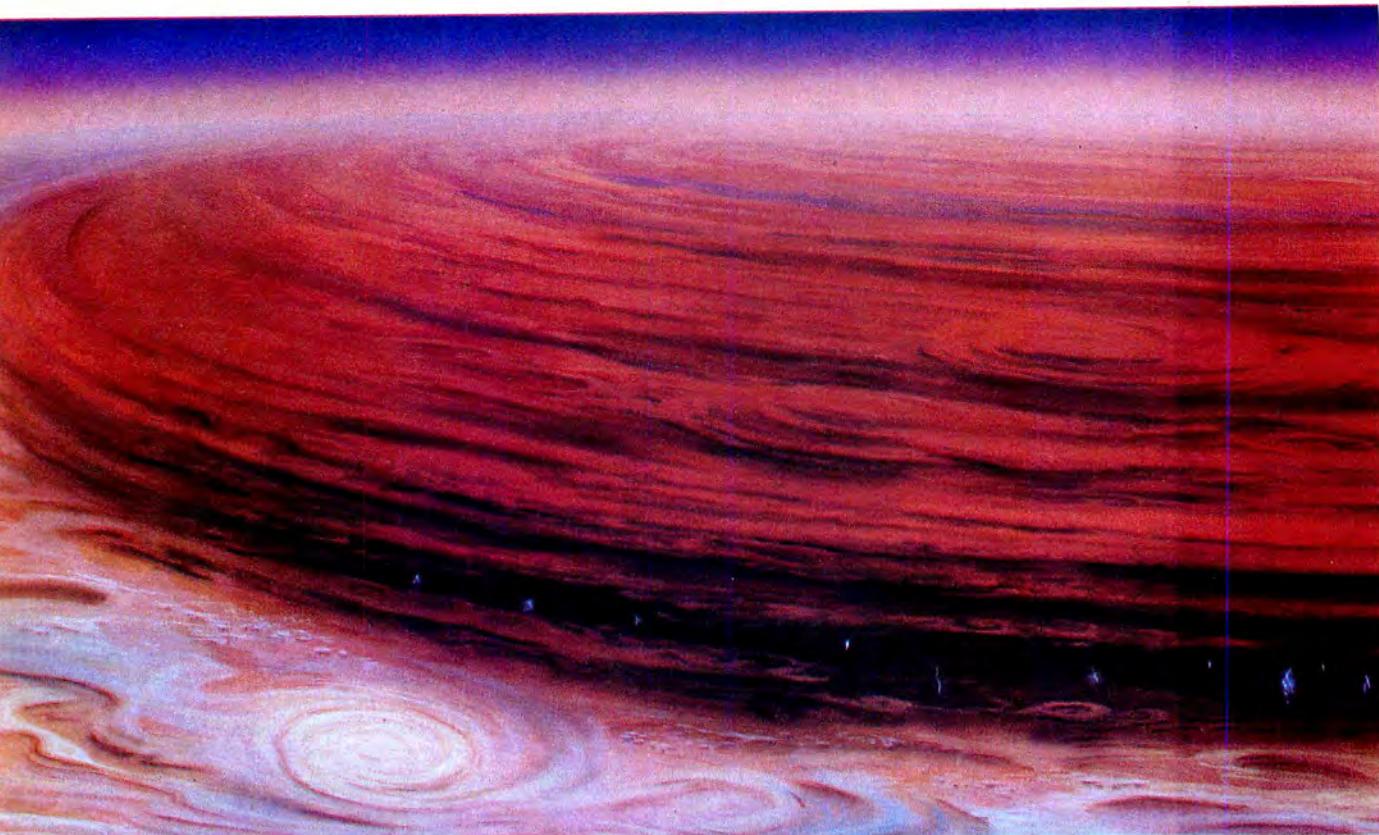


### *3. Earth's Oceans and Life*

Earth is the only planet with liquid water on its surface. More than three-quarters of our world is covered with water, in some places up to five miles deep. Water dominates the planet. It regulates weather, shapes the surface, and is probably the origin of terrestrial life. For the greater part of its presence on the planet, life has been concentrated in the oceans. Only in the last billion years have living creatures made a vigorous emergence onto land.

Here is a typical panorama from our misnamed planet. An extraterrestrial visitor flying past at random would have a 75 percent chance of seeing such a view. An undersea volcano is boiling huge clouds of steam into the atmosphere as it constructs new land, much as the distant islands may have risen above the sea. As new land is formed, the old is gradually worn away—the inexorable fate of the wave-battered rocks on the right, which are splotted with the green of primitive life forms, similar perhaps to the Earth's first living things. In the left distance, a pod of whales cavorts, enormous creatures of mysterious intelligence who abandoned the continents millions of years ago and returned to the security of the abundant sea.





## 4. Jupiter's Great Red Spot

In spite of two close flybys by terrestrial spacecraft, the Great Red Spot remains a mystery.

The spot has been a prominent feature on Jupiter for at least 300 years—the English physicist Robert Hooke may have observed it as early as 1664. The spot is, however, not a fixed feature: It drifts gradually westward and varies slightly in latitude as well, which rules out an early suggestion that the Red Spot might be a Jovian volcano. This notion was replaced by the “floating raft theory” in 1881, which described the spot as a solid object floating in the dense Jovian atmosphere. Whatever the object was, only its top surface showed, like an iceberg.

The most recent ideas—that it might be a vast storm similar to a terrestrial hurricane, or perhaps some kind of standing wave—fail to account for its uniqueness. Why is there only one Red Spot?

Whatever it is, it's enormous. With the exception of Saturn's rings or Sun spots, it is perhaps the largest single feature in the Solar System. At times it has measured as much as 24,000 miles long—three times the diameter of the Earth—and 8,400 miles wide.

Seen close up, the spot is a brick-red vortex of swirling clouds, layer upon layer, far above the lighter-colored clouds that surround it.

## 5. The Volcanoes of Io

Jupiter's moon Io is perhaps the most volcanically active body in the Solar System. Up to 200 volcanic craters larger than 12 miles in diameter pock its surface; the Earth has only 15. Voyager 1 alone observed nine different eruptions during its flyby in 1979.

On the horizon, an enormous plume of vaporized sulfur erupts to a height of 50 to 150 miles. Gravity one-sixth that of Earth allows material to be easily ejected to such impressive heights. The width of the umbrella-like plume might be as much as 600 miles. Sulfur is rocketing skyward at speeds of up to 2,000 miles per hour, many times faster than debris from a terrestrial volcano.

A representative volcano is shown here rather than any particular one, since Io's volcanoes are not continuously active. Nearby, a lake of black, molten sulfur boils away, adding new material to Io's lurid, ever-changing landscape. The thermal features are powered by Jupiter, only a quarter-million miles away. Tidal forces from the giant planet flex Io like a rubber ball in the fist of a body builder.





## 6. *The Great Wall of Miranda*

The nearest and smallest satellite of Uranus, Miranda is a tortured conglomerate of fractures, faults and blocks. The most amazing feature is the great cliff that was created when an enormous chunk of the moon's surface was raised above the surrounding terrain, leaving an almost vertical "scarp" nearly 10 miles high.

From our vantage point the wall looks like an undulating curtain of sheer, glass-like ice. If this towering wall were vertical, a steel-nerved astronaut could jump off its rim and not expect to hit the ground for four minutes. The experiment wouldn't be a good idea, however; he'd hit at the speed of a bullet, even under the feeble influence of Miranda's weak gravity.

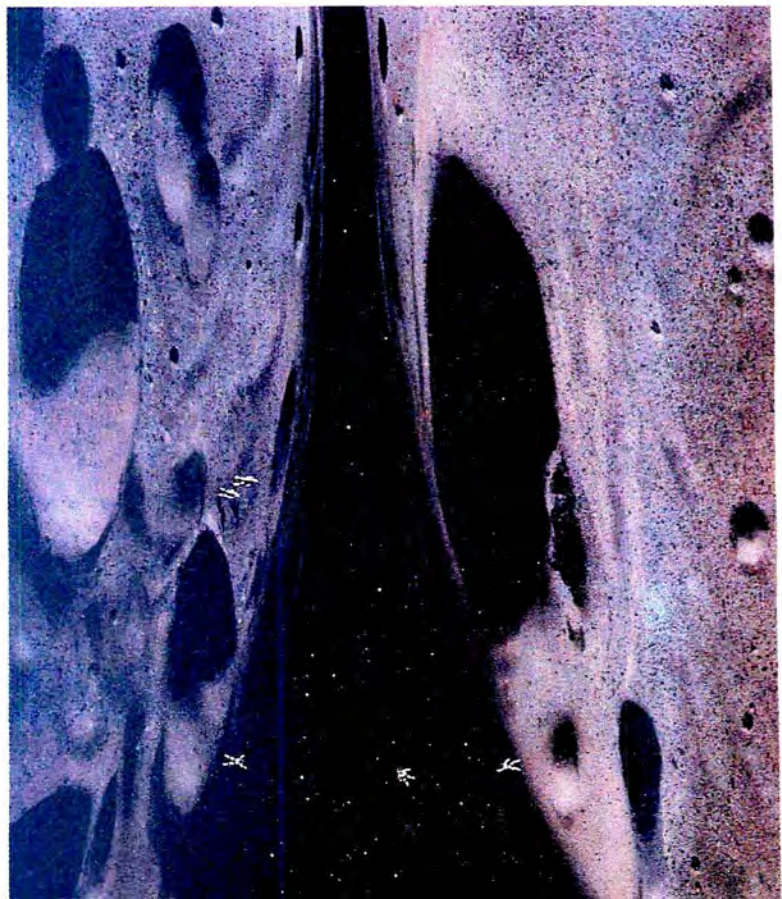
Uranus, 78,000 miles away, looks like an enormous blue balloon 88 times larger than the full Moon as seen from Earth.

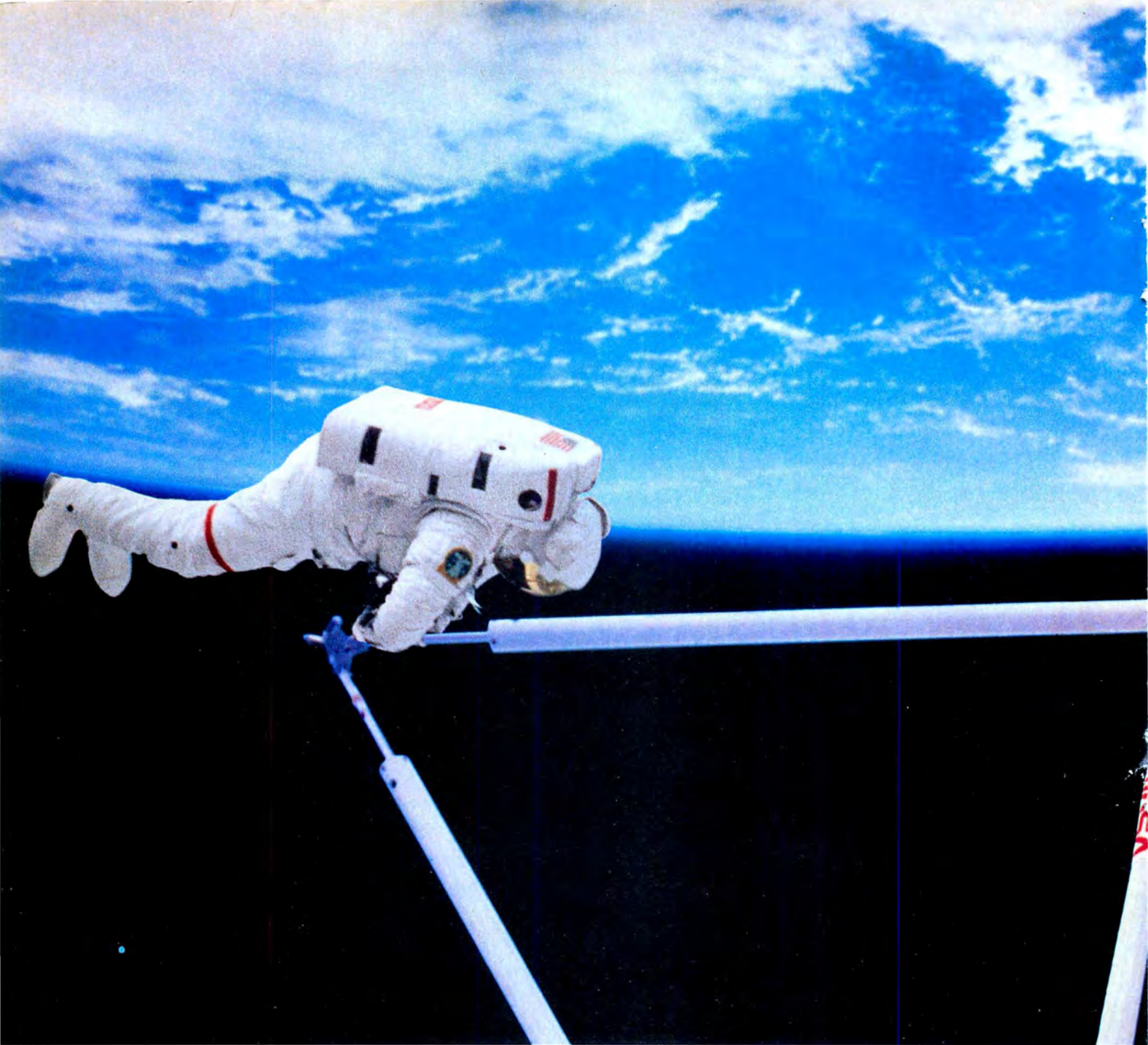


## *7. The Asteroid Hektor*

The only one of our seven wonders that is remotely human in scale, Hektor seems dwarfed in comparison with gargantuan features like the Great Red Spot. A tiny asteroid only 186 miles long, it varies greatly in brightness as it rotates—an observation that led astronomers Dale Cruikshank and William Hartmann to suggest the asteroid might be highly elongated, or even the result of two "normal" asteroids fused into a peanut shape after colliding. Another theory is that Hektor might be a binary asteroid, its two components slightly separated (perhaps only by a hundred feet or so) and orbiting around one another. The recent discovery of the half-mile-sized bi-lobed asteroid 1989 PB seems to suggest this may be a fairly common phenomenon.

What makes this little world so interesting is what we would see if we were to take a hike to the contact region. There we would find a mountain of rock nearly 100 miles wide hanging directly over our heads. Taking advantage of a gravity that would be less than one percent of the Moon's, we could literally jump to another world, like human spaceships.





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# Magellan's



## First Looks

**I**t was only a test, a promise of things to come, but Magellan project scientist Stephen Saunders had to admit that the first glimpses of Venus he saw in the wee hours of Friday morning, August 17, looked "pretty damn good."

Magellan had returned the images the day before, during a checkout of the spacecraft's cloud-penetrating radar in Venus orbit. The pictures—of two narrow strips of Venusian real estate running north-south through the rugged highlands of Beta Regio—revealed mountains, fractured plains and impact craters in 10 times the amount of detail seen in any previous radar pictures of Venus.

No sooner had Magellan sent back these perfect test images, however, than the spacecraft mysteriously placed itself in a "safing" mode, with its communication antenna pointed away from Earth—causing ground controllers a 14-hour panic before they could regain contact. When Magellan went off-line for another 17 hours five days later, project officials knew they had a problem.

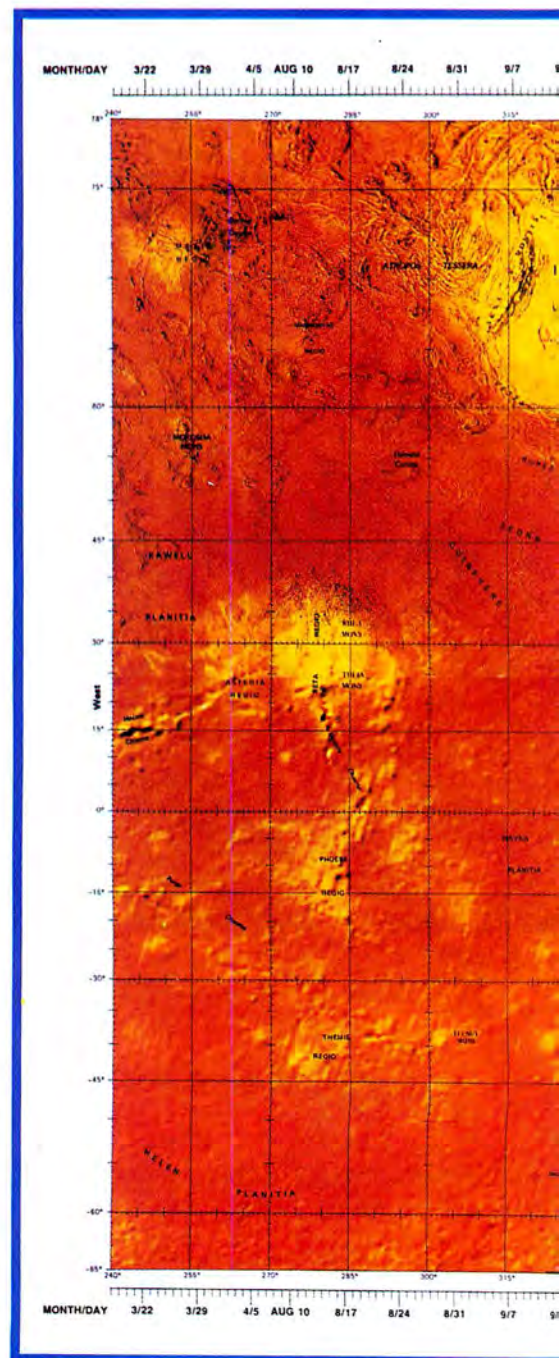
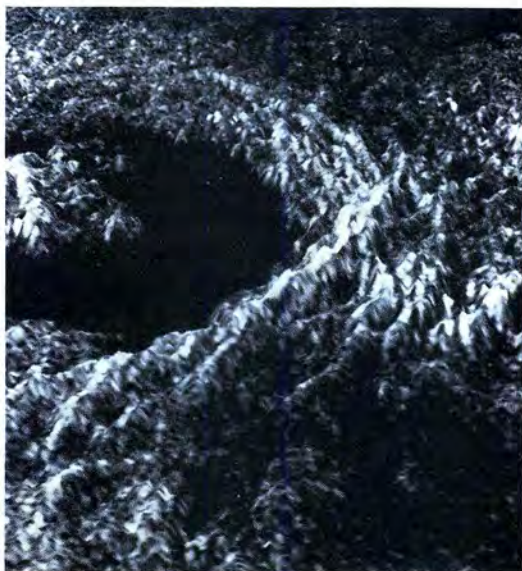
The erratic behavior was all the more mysterious considering that Magellan's trip to Venus had been flawless, a textbook study in how to launch an interplanetary spacecraft and park it in orbit around another world. So perfect was the "orbital insertion" maneuver on August 10 that Magellan used only half the fuel that had been budgeted for fine-tuning its orbit.

Even though project engineers were still at a loss to explain the spacecraft's problems in mid-September, they decided to resume mapping after loading Magellan's computer with a new program that allows them to

regain contact more easily should the spacecraft go AWOL again. Said Saunders: "It's better than standing down until everything's perfect."

So, for eight months, Magellan's radar will image one 16-mile-wide strip at a time, while the planet turns slowly underneath. After a full Venus year of 243 days, the radar will have mapped 70 to 90 percent of the globe, depending on how much data are lost due to spacecraft drop-outs, bad weather at Earth antenna sites and other unforeseen problems. Whatever gaps remain will be filled in during subsequent 243-day cycles.

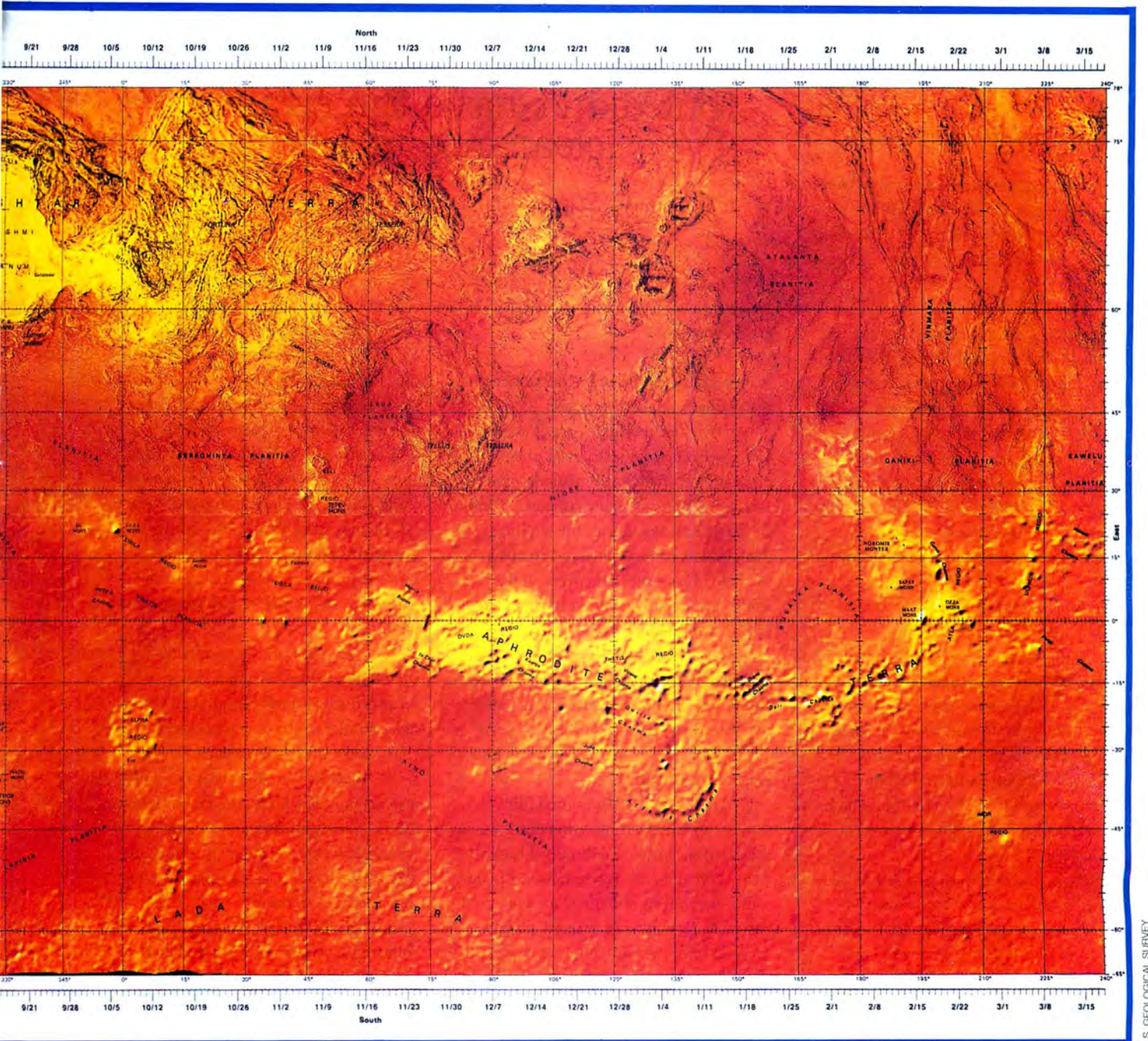
Every week or so, couriers will be rushing back to the Jet Propulsion Laboratory with tapes of data collected at giant Deep Space Network antennas in Spain, Australia and Goldstone, California. By the end of its first mapping cycle, Magellan will have sent back more information than all previous planetary missions put together—and given scientists a new understanding of our planetary next-door neighbor. □





**Left:** The crater Golubkina (named for the 19th-century Soviet sculptor Anna Golubkina) first appeared in radar images taken by the Soviet Venera 15 and 16 orbiters in the early 1980s (left half of photo), but Magellan's radar image (right half) revealed sharp new detail in the 20-mile-wide depression. The crater's terraced walls, central peak and rough material strewn outside the rim are all typical of a large meteorite impact crater. Before Magellan, scientists weren't sure if Golubkina had been created by an impact or by volcanism.

**Opposite page, lower left:** Unlike conventional photos, where shadows allow the eye to "see" three dimensions in a two-dimensional picture, Magellan's radar only distinguishes between smooth (dark) and rough (light) areas. During mapping, an altimeter onboard the spacecraft will be used to fill in information about height variations. In the meantime, computer enhancements like this view of the crater Golubkina approximate what the human eye might see. The smooth crater floor is similar to those found in lava-flooded impact craters on the Moon. Vertical dimensions in this computer image are exaggerated.



U.S. GEOLOGICAL SURVEY

This map created from U.S. and Soviet spacecraft data can be used to follow Magellan's progress around Venus. Magellan entered orbit on August 10. Its track will move eastward the rest of this year and into 1991. The mapping track for any day can be approximated by lining up the dates on the top and bottom borders of the map with a straightedge. The actual path is slightly curved.

Everything you always wanted to know about

# MILITARY SPACE PROGRAMS

1. We've heard stories about spy satellites that can read a license plate from orbit. Are these stories true?

Probably not. But there are satellites that can make out the shape of a vehicle, or see tank tracks in the desert, or tell you that someone is holding a newspaper even if they can't read the headline.

2. How important a role are these satellites playing in the Persian Gulf?

Reportedly, President Bush's decision to send troops to Saudi Arabia was supported by photos from spy satellites, which also helped convince the Saudis that Iraq might invade their country. Since then a full range of surveillance, navigation, communications and weather satellites have been involved in Operation Desert Shield.

Under a program called "Constant Source," fighter wings and other field units can tap into data collected in space using small, transportable UHF receivers. According to Major General Donald Hard, director of Air Force space acquisition, "Constant Source" is providing "mission essential" information to U.S. commanders in the Middle East.

While spy-sats take detailed photos of the region, signal intelligence (SIGINT) satellites in high geosynchronous orbit can monitor Iraqi communications. Troops also get important information from unclassified systems such as Defense Support Program (DSP) satellites, which can warn of an Iraqi ballistic missile attack.

Military communications satellites have helped coordinate the massive airlift of U.S. troops and supplies into the region, and according to Hard, "many of our F-16s, KC-135 tankers and B-52s are equipped with GPS [Global Positioning System satellite] receivers, which greatly improve their capability for accurate targeting." Desert forces even use data from military weather satellites—mobile termi-

nals provide near-real-time information to ground and air forces and to carrier battle groups in the area.

3. Are satellites the only component to the military space program?

No, but they're a large part of it. Military space officials like to break their program into two broad missions: "force enhancement" and "space support." Force enhancement includes all the satellites that support commanders and troops in the field. Space support covers all the things needed to get and keep those satellites in orbit: launch services, control centers, tracking stations and the like.

Probably the best-known spy satellites are the "Keyhole" series, which included the "Big Bird" (KH-9) of the 1970s. At any given time, an estimated two to four Keyholes are in orbit.

Originally, spy satellites used film cameras to take pictures. After a roll was shot, a film canister was dropped back to Earth so that an Air Force transport plane could snatch it in mid-air as it parachuted down. As technology advanced, charge-coupled-device (CCD) sensors replaced film. Using the same technology found in today's home video cameras, these systems can radio back images in near-real time to analysts on the ground.

While the Keyholes' vision is sharp enough to see the lines in a parking lot,

the satellites' polar orbits don't provide continuous monitoring of the Earth. They also can't see through clouds. So military technologists have turned to other parts of the electromagnetic spectrum for their pictures. Infrared sensors on DSP early warning satellites can detect and track the heat emitted by ballistic missiles. They also can be used to keep an eye on everything from space shuttle launches to tactical missiles launched by Iraq during its war with Iran in the 1980s. Future infrared systems may even be sensitive enough to spot artillery and exhaust from jet aircraft.

To observe at night or on cloudy days, the United States has a new system of polar-orbiting satellites equipped with radar similar to the one used by the Magellan spacecraft to map Venus. While these "Lacrosse" satellites lack the high resolution of Keyholes, their radar images can help analysts discern camouflaged missile launchers or tanks. By the mid-1990s there will be an estimated two to four Lacrosses in orbit.

Add to all those pictures a "soundtrack" collected by electronic sensors. These highly classified systems have gone by a number of code names, including "Rhyolite," "Magnum," "Aquacade," "Jumpseat" and "White Cloud." Flying in geosynchronous and polar orbits, they listen to radar transmitters, missile and



but didn't have the security clearance to ask.

by Richard H. Buenneke Jr.

spacecraft telemetry, and radio communications channels.

During peacetime, defense satellites provide important intelligence on weapons production and testing, and can help the United States monitor how well other nations comply with arms control agreements. Early warning satellites, which can detect missile launches or nuclear explosions anywhere on the globe, reduce the chance of a surprise attack and help steady the nerves of U.S. leaders during a crisis.

Like their civilian counterparts, military communication satellites provide global broadcast and two-way communications. They let the president relay orders to the entire U.S. nuclear arsenal or to a single fighter in the Persian Gulf. They also relay gigabits of bureaucratic data to and from the Pentagon, and transmit Christmas messages and family news to soldiers and sailors far from home.

Unlike data from their civilian counterparts, however, data from these military communications satellites are encrypted for secrecy, as are the data from defense weather satellites that help military forecasters decide if paratroopers planning to drop in halfway around the globe should pack a raincoat.

Another military space system may well revolutionize warfare in the next century. When fully deployed in the mid-1990s, the Navstar Global Positioning System (GPS) will give U.S. forces nearly instantaneous fixes accurate to within 16 meters—a 10-fold improvement over existing systems. The eighth in a constellation of 21 GPS satellites was launched last August.

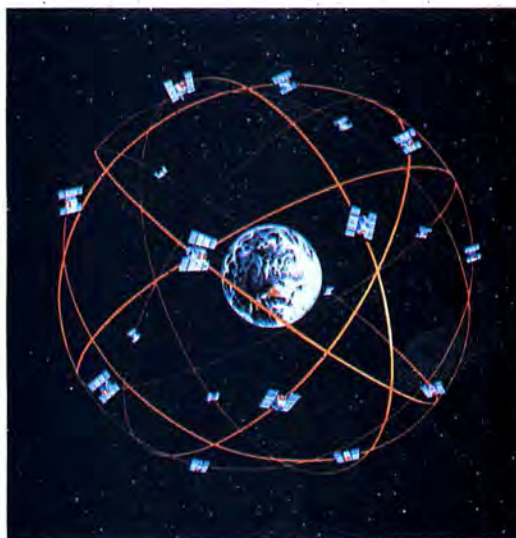
#### 4. Who runs all these programs?

Most are operated by U.S. Space Command, a joint organization that includes Air Force, Navy and Army units. Established in 1985, Space Command is gradually assuming day-to-day responsibility for military satellites and launch vehicles.

The Command's 16,000 personnel are located at bases around the globe, but the hub of activity is in three Air Force bases located near Colorado Springs. One of the

bases, buried inside Cheyenne Mountain, serves as the primary early warning center. Another base located east of town eventually will serve as the mission control center for most defense satellites.

Reconnaissance and eavesdropping satellites, meanwhile, are operated in secret by the CIA and military intelligence organizations, which have their own tracking and command centers. According to sources familiar with the intelligence community, the CIA and Air Force develop competing designs for optical and radar spy satellites. Eavesdropping systems are developed by the National Security Agency. Once the intelligence community decides which satellites it wants, it gives its specifications to the National Reconnaissance Office (NRO), the lead spy satellite organization. Operat-



**The Global Positioning System (GPS) gives soldiers and civilians alike an exact fix on their location.**

ing under the cover name "Air Force Office of Space Systems," the office supervises satellite construction and launches.

Intelligence officials say this cloak-and-dagger management setup helps conceal the true capabilities of U.S. spy satellite systems. More cynical observers note that secrecy also proves useful when the spacecraft don't work right or generate huge cost overruns.

#### 5. Isn't there also a lot of basic space research conducted by the Depart-

#### ment of Defense?

Since space uses so much high technology, Space Command is often overshadowed by the agencies responsible for research, development and acquisition. The Air Force, which is the lead service for procuring boosters, satellites and ground support hardware, also conducts military research on space technologies in a number of laboratories around the country. Other space research is sponsored by the Navy and the Defense Advanced Research Projects Agency (DARPA), which fund work on everything from small, inexpensive "lightsats" to satellite submarine laser communications.

The single biggest sponsor of space research is the Strategic Defense Initiative (SDI) office, which runs the Pentagon's antiballistic missile effort. Over half the \$3.5 billion spent each year on "Star Wars" goes for research on advanced space sensors and weapons.

Not all SDI money goes directly to aerospace contractors, however. Some goes to fund research at weapons laboratories run by the Energy Department. Los Alamos National Laboratory, for example, specializes in beam weapons and space nuclear power. Its rival, Lawrence Livermore National Laboratory, is leading work on orbiting "Brilliant Pebbles" interceptors (see below).

#### 6. That sounds pretty expensive. How much does the military space program cost?

Because the CIA and other intelligence agencies are cagey about publishing their budgets, it's hard to get an exact total on spending. Using the best available data, it appears that the federal government spent over \$18 billion this year on military space programs. NASA, by comparison, spent \$12.3 billion.

Approximately 80 percent of the military spending is included in the Air Force budget. Around \$8 billion goes to build, launch and operate spy satellites. Another \$8 billion goes for unclassified early warning, communications, navigation and weather satellite programs and general



DEPARTMENT OF DEFENSE



DEPARTMENT OF DEFENSE



J. STATTON/SPACE SURVEILLANCE CTR

**The Air Force's shuttle facility at Vandenberg AFB in California (left) never saw a single launch, despite the \$4 billion price tag. Spacecraft like the DMSP military weather satellite (which took this night-time view of the United States) are tracked by the U.S. Space Command's Space Surveillance Center in Colorado.**

space research. The remaining \$2 billion is spent on SDI space programs, which account for more than half the total SDI budget.

The military's \$18 billion budget is roughly twice what it was a decade ago—largely due to the Reagan administration's defense buildup, the start of SDI research, and increases in the number, complexity and cost of satellites. While all satellites have to be "hardened" against the harsh environment of space, military spacecraft also must be protected from jamming, anti-satellite weapon attacks, laser blinding and nuclear explosions. All of these requirements drive up development costs. Even a fairly simple military satellite can cost around \$170 million to build and launch. The proposed Milstar satellite—which faces cancellation by Congress—would use extremely high frequencies and elaborate computers to provide communications after a large nuclear attack. Each Milstar would cost \$1 billion to build and launch. Costs for a comparable civilian system are around \$80 million per satellite.

While overall defense spending is expected to decline in the 1990s, most experts expect military space budgets will stay steady or even increase slightly. Top Pentagon officials believe that space systems provide an important "force multiplier" that will compensate for proposed cuts in ground, air and naval forces.

### 7. Isn't the military also building space weapons?

Despite all the computer simulations you've seen on the evening news, the United States currently does not have any weapons to shoot down either satellites or

ballistic missiles. But that's not for lack of trying by the Reagan and Bush administrations.

Reagan had hoped to have an anti-satellite (ASAT) weapon deployed by now. But the program, which used a heat-seeking missile launched from an F-15 fighter, was canceled in 1988 when Congress refused to permit tests against satellites.

After going back to the drawing board, the Bush administration approved an Army plan to develop a ground-launched ASAT capable of knocking out enemy satellites flying at altitudes up to 1,200 miles. The Army plans to spend \$2 billion to \$2.5 billion to develop and deploy about 50 of these ASATs at a single site, probably an American territory in the Pacific. Whether Congress will let the system be fielded in the mid-1990s is an open question.

Work on anti-missile weapons is moving at a slower pace. SDI experiments have demonstrated that it's technically feasible to "hit a bullet with a bullet," but the program still hasn't shown it can accomplish that goal at an affordable price.

SDI advocates are now placing most of their bets on the "Brilliant Pebbles" concept, which would deploy several thousand 100-pound interceptors in low Earth orbit. If it received orders from the ground, each pebble could use onboard sensors and a supercomputer to fly into an enemy missile.

While most experts agree Brilliant Pebbles are feasible, nobody has a definite idea of how to control or build them. The Pentagon's SDI organization estimates a two-layer system of pebbles and ground-based defenses would cost around \$50

billion to build and deploy. Other military experts believe costs could be significantly higher.

While exotic laser and particle beam weapons are what gave President Reagan's SDI program the nickname "Star Wars," this research is now on the back burner. And no one any longer envisions the leak-proof "peace shield" that some SDI advocates once touted. The program's value is seen primarily as deterring a first strike.

### 8. Don't military space programs overlap with civilian programs? Why can't the two sides work together?

Like their civil and commercial counterparts, military space program managers want low-cost, reliable launch vehicles and upper stages. They also want smaller, more capable onboard computers, power sources that pack more watts into a kilogram and communications systems that can operate with small mobile ground terminals. These common interests can lead to close cooperation between military and NASA research programs.

In the field of space transportation, the Defense Department and NASA are already cooperating on the Advanced Launch System (ALS) program, which aims to improve both the efficiency and capability of today's launchers. ALS was originally conceived as a heavy-lift booster for deploying the SDI missile-defense system. But SDI's move to Brilliant Pebbles has taken away the requirement for a booster capable of lifting 50 to 100 tons into orbit.

Trying to find money to pay for its bomber and fighter programs, Air Force generals decided to throttle back on ALS. Under current budget plans, the program

will focus on engine technology for the next several years, delaying vehicle development until late in the decade.

While trading rockets for planes makes sense for the pilots who run the Air Force, some in Congress believe the service should consider speeding up development of smaller versions of the ALS. They point out that the Titan 4—the Air Force's current workhorse booster—is having many of the same cost and schedule programs encountered on the shuttle. While the Air Force says it can improve Titans by adding ALS technology, many rocket experts think the nation needs a booster designed from a "clean sheet" to compete with future European and Japanese boosters.

Civilian and military space engineers are also working together on the National Aerospace Plane program and on ion engine research. Work on space nuclear power systems, autonomous spacecraft and improved power systems is funded in both military and NASA budgets.

Defense scientists also share results with civilian researchers on the natural space environment, particularly with regard to potential threats such as orbital debris and space radiation. Military labs publish results from basic Earth and space science research, and the Naval Research Laboratory has even flown two civilian scientists—Paul Scully-Power and John-David Bartoe—on the space shuttle.

### 9. Has the Pentagon ever wanted its own manned space program?

The history of "military-man-in-space" is full of programs that began with great expectations but eventually dribbled off into nothing.

During the early 1960s, the Air Force sponsored research on the X-20 Dyna-Soar—a spaceplane that bears a striking resemblance to the Hermes vehicle now being developed in France. After Dyna-Soar was canceled by the Kennedy administration, the Defense Department moved on to another ill-fated program, the Manned Orbiting Laboratory (MOL).

As conceived by the Air Force, MOL would have used a Gemini capsule connected to a small orbiting laboratory. Military astronauts would have lived in the lab and taken reconnaissance photographs of targets below. Several astronauts who later went to work for NASA—including

Robert Crippen and shuttle pilot turned NASA administrator Richard Truly—started their space careers in the MOL program.

But MOL was canceled by the Nixon administration, which decided that automated "Big Bird" satellites were cheaper. Some national security planners were still intrigued by the idea of using astronauts to deploy and repair reconnaissance satellites, however, and when NASA came around selling its shuttle program in the

1970s, civilian Pentagon leaders agreed to sign up for one out of every three missions. In return for making the shuttle large enough to carry spy satellites, the Air Force agreed to phase out its expendable rocket fleet and to build a polar launch facility—actually a \$4 billion upgrade to a pad built for the MOL program at Vandenberg Air Force Base in California.

The military's shuttle madness reached its peak in the early 1980s. Reporters

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were told not to "speculate" on the identity of classified payloads flown on blacked-out missions. A senior Air Force official even suggested that the Vandenberg pad should be christened the Ronald Reagan Space Center. But the risk of relying on the shuttle as the sole national space transportation system became evident to Pentagon officials long before the Challenger disaster. Concerned that the shuttle wouldn't be able to launch critical payloads, the Air Force moved some satellites back to unmanned boosters.

After Challenger blew up, Pentagon officials pulled practically everything off the shuttle, and the pad at Vandenberg was written off as a total loss. Only payloads that couldn't be adapted for unmanned boosters remained on the shuttle, and except for some unclassified SDI science experiments, the military shuttle program will end early next year.

Of course, no dream ever completely dies in the Pentagon bureaucracy. Some military planners continue to suggest a need for sending military personnel into orbit as scouts and satellite repair workers, or even for establishing military outposts



Defense dollars are helping to build new vehicles like Orbital Sciences's Taurus.

ORBITAL SCIENCES

on the Moon and other space "choke points." But this planning is not taken seriously by most senior Pentagon officials. Although the Defense Department would like to reserve the option to conduct science experiments on NASA's space station Freedom, most generals believe military man-in-space experiments are just another way for ambitious young officers to wangle joyrides in orbit.

#### 10. So much for a U.S. Starfleet. But can the military make any contribution to the human exploration of space?

Even though relations between the Pentagon and NASA were strained by the

shuttle, it's important to remember that the military has *always* provided extensive support to manned space missions. Mercury and Gemini capsules were launched on converted boosters developed by the Army and Air Force. Every Mercury, Gemini and Apollo mission was recovered by a Navy carrier. And today, the Defense Department continues to provide extensive support for shuttle missions. Air Force officers give weather and range safety support during launches. Space Command's space surveillance network ensures that orbiting shuttles don't fly through large concentrations of space junk. In 1981, Air Force space surveillance cameras even took pictures of Columbia to make sure its thermal tiles hadn't fallen off.

Although the military won't play much of a role in the space station Freedom program, President Bush has stated specifically that he wants the Departments of Defense and Energy to participate in his Moon-Mars Space Exploration Initiative. Air Force officials say they could con-

*continued on page 38*

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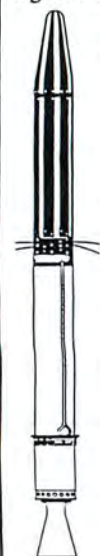
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*continued from page 36*

tribute by developing and operating ALS boosters to lift components for lunar bases and Mars ships into Earth orbit.

Scientists at the Department of Energy's weapons laboratories, meanwhile, have all sorts of ideas for cutting the cost of human space exploration. One group led by Lowell Wood at Lawrence Livermore has suggested using inflatable modules as habitats in orbit, on the Moon and on Mars. Scientists at Los Alamos are interested in using nuclear reactors to generate power and to drive rocket engines. And some military robotics research—particularly in the area of teleoperations—may be applicable to future space missions.

## 11. Could military programs benefit the commercial space industry as well?

Although the Air Force wants to retain control of spy satellite launches, the Pentagon is willing to buy commercial Atlas and Delta boosters for its communications satellites. This should help provide the U.S. launch industry with a guaranteed revenue base—commercial launch companies already rent Air Force launch pads.

The Pentagon also helps to bankroll research on innovative space ventures. The best example of this is the Defense Advanced Research Projects Agency's "lightsat" program, which funded the first flight of the Pegasus air-launched booster last April. DARPA also is buying the first flight of Taurus, a larger, ground-launched variant of Pegasus also built by Orbital Sciences Corporation.

In addition, DARPA and the Navy are sponsoring development of small communications and surveillance payloads. Since these lightsats would be controlled directly by commanders in the field, they could be adapted by commercial ventures to provide cellular telephone or remote sensing services to consumers.

Giving infant companies the seed capital they need to get on their feet also serves the military's long-term interests. In recent years, the Pentagon's procurement system has lagged well behind the market. In fields such as computing, military programs are sometimes two or three generations behind commercial users. By spending a small amount of funds on lightsats and other innovative concepts, the Pentagon could help make the space



SANDIA NATIONAL LABORATORIES

## Driverless sentry vehicle: Can military research into telerobotics be of use in planning Moon/Mars explorations?

industry as vibrant as the computer business. The resulting advances could then improve military systems.

## 12. But doesn't military involvement in civilian programs go against the U.S. commitment to the peaceful exploration of space?

It depends on your view of history.

When NASA was established in 1958, space was seen as an important element in the strategic competition between the United States and the Soviet Union. Taking the moral high ground, the Eisenhower and Kennedy administrations decided to keep the civilian program as open as possible. Under this plan, NASA would demonstrate the nation's technical competence while the Defense Department quietly pursued military applications.

Now that the Cold War is winding down, it may no longer make sense to maintain a rigid separation of military and civilian programs. Instead, it may be a good idea to return to a more traditional division of exploration responsibilities.

For most of the nation's history, the military played a very active role in exploration. Army scouts from Lewis and Clark through Pike mapped much of the American West. Navy officers led expeditions to the North and South Poles.

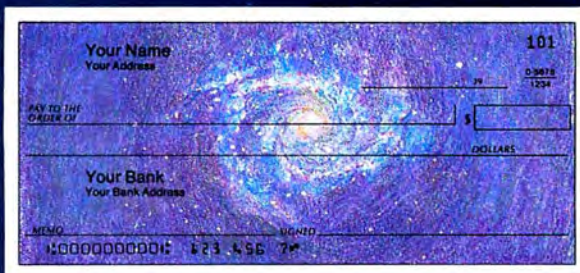
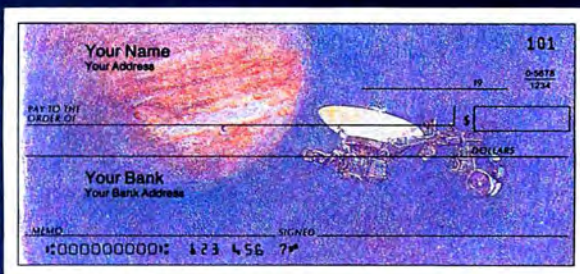
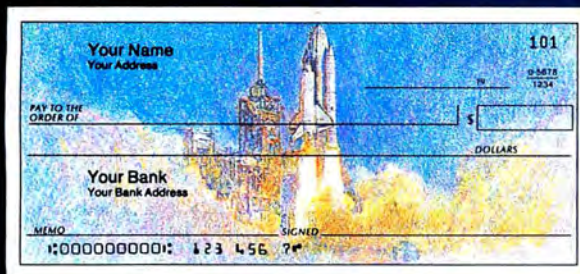
Even today, the Navy and Air Force provide substantial support to research stations in Antarctica. Military ships and aircraft ferry supplies to scientists, even though the continent is a demilitarized zone under international law.

In addition to providing similar support to a lunar or Mars base, military programs could provide NASA with some friendly competition. For the Pentagon,

*continued on page 40*



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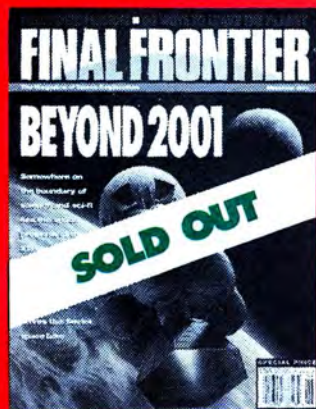
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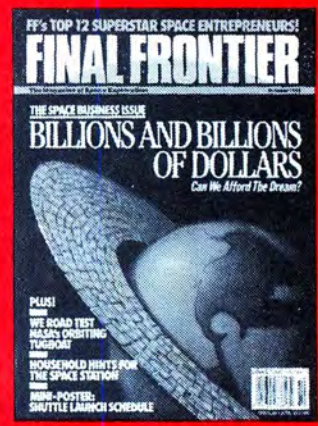
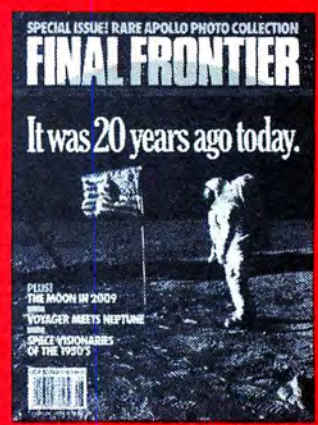
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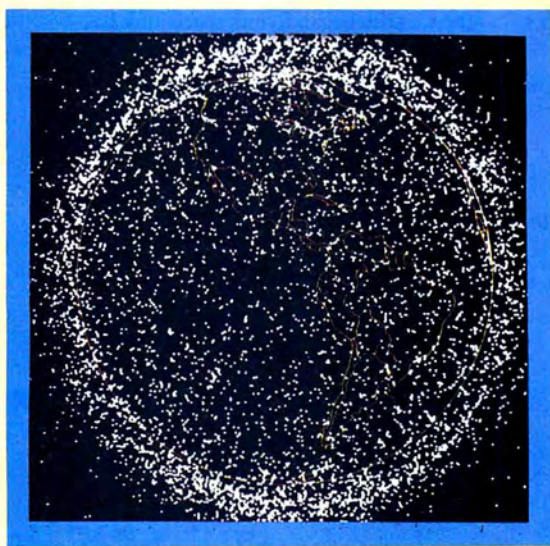


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# **THE ORBITING**

Everybody talks about space debris,



Computer map  
of orbital debris,  
circa 1987.

but is anyone doing anything about it?

# **JUNKYARD**

BY GREG FREIHERR

**T**he high-pitched whine of a mirror rotating a million times per second fills the 5,000-square-foot laboratory. At the other end of the garage-like metal building, an operator turns the key that arms an explosive charge. A flip of a switch and the laboratory rattles with the blast of gunpowder.

What seems like an exotic weapons test is actually the latest in a series of experiments aimed at understanding the effects of space junk on satellites in Earth orbit. Gunners at NASA's Johnson Space Center (JSC) in Houston have blasted away at aluminum plates, shuttle tiles, windows, sheets of graphite-epoxy planned for use on space station Freedom—even space suits. The whining, turbine-driven laser camera records the impact of the .17-caliber projectile in 80 "shadowgraphs"—stop-action pictures of shadows produced when the slug smashes the target.

"We're trying to find clever, lightweight solutions to stopping those projectiles, because we're going to end up having to stop debris about that size for the space station," says Eric Christiansen, a research engineer in the JSC Hypervelocity Impact Research Laboratory.

The .17-caliber gun is one of three blasters in the hypervelocity lab that can accelerate projectiles to five miles per second or more—typical speeds for objects circling between 100 and 500 miles above the Earth. That region is populated by most Earth observing satellites, the shuttle, the Soviet Mir space station, and, eventually, the NASA/international space station.

It's also the haunting grounds of several million pounds of man-made junk.

Most of that mass is worn-out satellites and rocket bodies, with a few odds and ends, including a glove from an Apollo 9 space walk and a camera lost by Michael Collins during his Gemini 10 flight, thrown in for good measure. But by number, the junk circling the Earth consists mostly

of tiny chips, flecks and slivers from exploded rockets and satellites, along with bolts, screws and clamps.

As of December 8, 1989, the U.S. Space Command had 6,567 trackable objects in its catalogue of Earth satellites, of which 4,932 were in low Earth orbit. And those are only the objects 10 centimeters or larger, which can be tracked by radar from Earth. Debris between 1 and 10 centimeters make up about 17 percent of the orbital junk. Particles smaller than 1 centimeter account for another 78 percent.

Earth orbit transforms these bits of debris, some no bigger than a pinhead, into micro-bullets. In 1983, a fleck of paint no bigger than a grain of sand chipped Challenger's cockpit window like roadside gravel hitting a windshield. Since the shuttles began flying, space junk has damaged 22 of their windows. Half, including the Challenger window, had to be replaced.

Debris impacts have pitted the windows of every type of American manned spacecraft since Mercury, and have been recorded with special experiments flown on Gemini, Skylab and the shuttle. The Palapa and Westar satellites retrieved by

shuttle astronauts in 1984 showed debris damage when inspected back on Earth. So did surface materials removed from the Solar Max satellite, which was repaired by spacewalking astronauts in 1984 after four years in orbit.

The Long Duration Exposure Facility (LDEF), picked up by Columbia last January after almost six years in space, promises to give engineers more understanding of the effects of orbital debris. Preliminary study revealed that LDEF had been pelted with tiny shards of debris and micrometeoroids, showing at least 5,000 hits.

"We've seen a lot of craters within craters, small pits located all around the interior, which indicates that possibly the particles were some kind of a matrix or a cluster of small particles that were traveling very close together," says William Kinard, LDEF chief scientist at NASA's Langley Research Center in Hampton, Virginia.

"The largest crater we saw on LDEF was about five millimeters in diameter," Kinard says, "and I wouldn't have expected that crater to have caused any critical damage in terms of survival of a



**Microscopic pits like these appeared in pieces returned from the Solar Maximum Mission satellite after four years in orbit. The holes—numbering six per square foot—were probably caused by impacts with tiny paint flakes.**

space station. If it happened to hit an instrument it might cause a malfunction, but there was nothing detected on LDEF that would indicate the risk of a critical failure to the station itself."

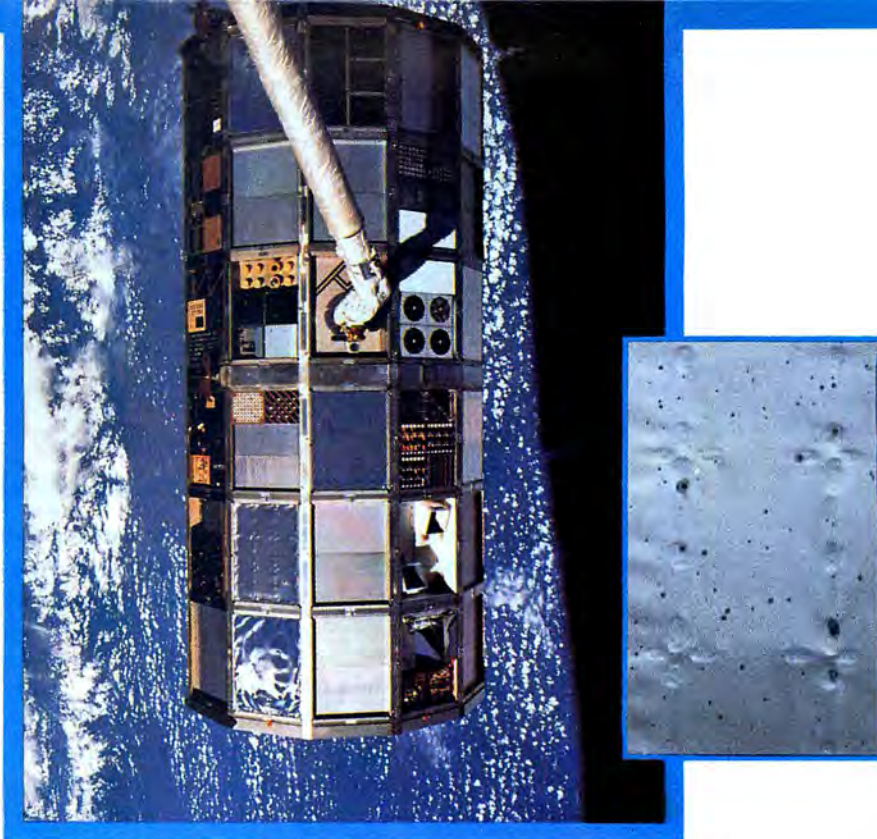
Although NASA and military space officials have been aware of the orbital debris problem for years, planning for space station Freedom has led to new concern—and a new round of studies. Unfortunately, predicting the spread of debris is a very uncertain business. It depends in part on the pace of future space activity and the reliability of future spacecraft. As more nations—and even commercial companies—develop fledgling space programs, the threat posed by space debris may grow worse. Some experts believe that an orbital apocalypse is near at hand, when the level of debris will begin triggering a chain-reaction of secondary collisions. Small particles would smash into larger pieces, which would break up and smash into more pieces—on and on until the Earth is surrounded after a few years by a ring of garbage.

How to get rid of all that junk? Luckily, some of the debris in low Earth orbit is cleaned up naturally by regular fluctuations in the Sun's energy output. In recent years, high solar activity has heated the upper atmosphere, causing it to expand and drag some of the junk down to where it burns up on re-entry.

But, says Darren McKnight, associate professor of physics at the U.S. Air Force Academy in Colorado, "Solar activity may have peaked out a number of months ago. The free lunch is over."

Therefore, says NASA's Kinard, "Man has to conduct operations up there so as to protect the environment. [The problem] is probably more critical than it is on Earth, because should we have one explosion that produces a large amount of debris, we could very easily make space totally unacceptable for a space station for years."

Faced with trying to operate a large space station in orbit for 30 years, NASA and other world space agencies are beginning to develop a space environmental consciousness. Along with the U.S. Department of Defense, NASA has taken steps to prevent the biggest source of space pollution—rocket bodies left in orbit. In the past, these have exploded in space due



**NASA'S Long Duration Exposure Facility also showed a peppering of small debris impacts (inset) after nearly six years in space.**

to the continued stress of residual fuel expanding and contracting during passage through the day and night sides of Earth. The problem is solved by venting the fuel. Operators of the European Ariane rocket—which left hundreds of debris particles in orbit after a third stage breakup in 1986—also have taken this preventive measure.

These and other recent international actions, such as the Soviets' decision to detonate spent military satellites at lower altitudes, has led to a decrease in the number of breakups in orbit—from five to ten per year to about one per year.

Still, McKnight would like to see these upper stages removed from space entirely. The simplest means of doing so is to use the engine as a retro-rocket. But this would add extra fuel, and consequently leave less room for payload.

In another scheme, balloons might be inflated behind upper stages and satellites that have ended their useful lifetimes. A balloon only 20 yards in diameter would be large enough to drag in Earth's rarified upper atmosphere, slowing the satellite until, within several weeks, it would re-

enter and burn up.

"That kind of technique is particularly applicable to spacecraft that don't have [onboard] propulsion," says Joseph Loftus, an assistant director at JSC. "The spacecraft would re-enter eventually, so you aren't increasing any terrestrial hazard. But you are substantially reducing orbital hazards, which seems like a pretty fair trade."

To get at the mess now in orbit, some engineers have proposed a futuristic fleet of garbage collectors. One type would orbit the Earth, grappling derelict spacecraft and sending them plunging into the atmosphere or into a junk heap of spare parts and raw materials safely circling the Earth. Another proposal is to rendezvous with a large piece of debris, attach a tether, then rope it down into the atmosphere where it would burn up.

There may be serious problems, however, when grappling uncooperative satellites that contain hazardous materials, lack built-in grapple holds or are tumbling erratically. There are also legal concerns about one government disposing of another's property.

Since small debris doesn't present the same problems, it might be cleared with space "sweepers." Donald Kessler, a JSC program scientist, has proposed the use of foam-filled balloons a mile or more in diameter. Small debris would either be trapped in the balloon or bounce off it, slowing enough to drop out of orbit. The one drawback is that this space "nerf ball" might collide with anything in its path—junk and working satellites alike.

Some debris experts, therefore, prefer the "space mills" concept—a sweeper with panels several square miles in area that would turn around a core spacecraft like the vanes of a windmill around their hub.

"The core would monitor objects on a collision course with the sweeper, controlling the rotation rate of the vanes to selectively avoid or collide with objects," says Andrew J. Petro, a scientist in the JSC Advanced Programs Office. Several sweepers would have to operate simultaneously to be effective, Petro says. The investment would be high. He suggests that sweepers might be more practical if they were applied on a smaller scale—to capture debris from an explosion or collision of two objects, for example. "This type of operation would be similar to clean-up activities after a marine oil spill," Petro says. Several space mills might also be used as shields for space station Freedom, flying ahead and alongside the station like a convoy of supply ships, picking off any particles that might damage it.

One major hitch in these schemes is money. Actively cleaning up space could cost billions of dollars, and the United States is not likely to want to foot the bill alone. As more nations leap into orbit, responsibility for keeping space clean will be shared.

Meanwhile, the near-term solution to the debris problem is to "harden" satellites—especially the international space station—against impacts. Aside from the threat to astronauts if one of the crew



**Debris hitting a conventional "Whipple Shield" (right) strikes an outer bumper, then spatters against a back wall. An advanced shield being tested by NASA (left) would have several bumpers to absorb the shock of impact.**

modules took a direct hit, damage to critical navigational equipment or a fuel tank could be catastrophic to the station itself. A large, fast-moving object could conceivably bring the entire complex down.

How much risk to the station would be acceptable? Karl Henize, an astronomer at JSC, says "there comes a point when you spend so much money trying to eliminate risk that it gets too expensive to do anything."

Henize, a former shuttle astronaut, believes engineers may be making a mistake by overemphasizing safety, and that the public and astronaut corps of the 21st century will have to accept the possibility of death in space. Currently, NASA designers have made it their goal to achieve a 99.55 percent certainty that the station will not experience a critical failure in the first 10 years of operation. The underlying logic was to have no more risk of losing a crew member to a debris impact than to a major solar flare or any other space phenomenon.

To stay safe, the space station will occasionally—perhaps as often as several times a year—have to play the role of an orbital boxer, bobbing and weaving out of the path of potentially catastrophic debris. Plans are already in the works to build debris detection systems that would complement ground-based tracking from the U.S. Space Command to give the station crew enough of a "heads-up" to take evasive action.

A rudimentary warning system has been in place since the beginning of the U.S. manned spaceflight program. But for

most of this time, warnings issued by the Space Command, formerly NORAD, were just "advisories." That changed after the Challenger explosion. Safety rules now call for the shuttle to dodge any debris 10 centimeters or larger passing within an elliptical sphere measuring 2 by 2 by

5 kilometers surrounding the orbiting spaceplane.

Only once since the shuttle's return to flight in 1988 has Space Command issued such a warning. During the secret STS-27 mission in December 1988, a piece of space debris unexpectedly showed up on the radar screens, recalls Mark Haynes, a flight dynamics officer at JSC. "It was a fluke. Sometimes Space Command happens to pick up an object they haven't seen for several weeks."

Despite the warning, no evasive action was taken. "There was only about 30 minutes' notice," says Haynes, "and 30 minutes is not enough time to plan a burn, execute it and have it do any good." Shuttle flight controllers need a minimum of 12 hours' notice to adjust the spacecraft's orbit. Those charged with keeping the space station safe presumably will need at least that long to dodge a large object. Unless the unexpected happens, as in the case of the 1988 shuttle mission, adequate warning time should be possible, according to Loftus.

"There are predictable directions in which to look for things that are a threat to the space station, and that's what leads one to believe that collision avoidance is practical," Loftus says. "But we have a lot more work to do in that area."

A passive debris collision warning sensor is scheduled for testing onboard the shuttle in 1994. The passive system will use reflected sunlight and earthlight—either visible or infrared—to detect even smaller objects that don't require evasive action. A practical system using this tech-

nology could provide about two minutes' warning that an object one to ten centimeters in size is likely to hit the station. That would give the crew enough time to close hatches, power down critical systems and move to a designated "safe haven" on the station. "You would seal off and compartmentalize, much as is possible on ocean liners," Kinard explains.

Some engineers would like to hook this kind of warning sensor to a weapon that could vaporize incoming debris. No such system—with so little room for error—has ever been built, but one is being designed.

Engineers at JSC are working on plans for a phased array radar that could acquire and track debris particles 10 centimeters or larger. Initial fixes would come from Space Command. The system would also scan for smaller particles that sneak by ground-based trackers. Current designs call for an antenna about 5 meters square, capable of picking up 1-centimeter particles at a range of about 60 miles. That would give the system about 10 seconds to lock onto the target and fire a laser beam, a concen-

trated dust cloud or an electrical charge that would encircle the oncoming particle, interact with the Earth's magnetic field and cause the intruder to plunge into the atmosphere.

"We really haven't done the detailed work, either analytically or experimentally, to demonstrate that the sensors and the data-processing algorithms are truly practicable," Loftus says.

Of course, if there were no limit on how much could be spent to protect the space station, most debris fighters would opt for Defender. Proposed by BDM International, Inc., of Huntsville, Alabama, this small, fully computerized spacecraft would ride out ahead of the station—identifying, tracking and then getting in the way of anything that comes too close.

The computer brain guiding Defender would have to distinguish between friendlies—such as arriving space shuttles and astronauts working outside the station—and debris. Some engineers have their doubts that this can be done in the near future. And an even greater concern is

that Defender might do its job so well that it's blasted to smithereens by a large chunk of debris.

"The pieces could do more damage to the station than would have been done by the single particle it intercepted," says JSC debris expert Ray Nieder. These concerns, along with the incredible expense of such a system, appear to doom Defender to never making it farther than the borders of a computer screen.

More to NASA's liking is the concept of a shelter where Freedom's crew could huddle in times of emergency. Putting this storm cellar in the center of the station, nestled between the large manned modules, would insulate it from impacts. Extra shielding, especially in areas vulnerable to direct impact, could make it even safer.

This also would cost money, however—apparently much more than anyone at NASA wants to pay. A new module means a new space station design, at a time when Congress is shaking its collective head over the cost of the present one.

Just adding enough shielding to protect

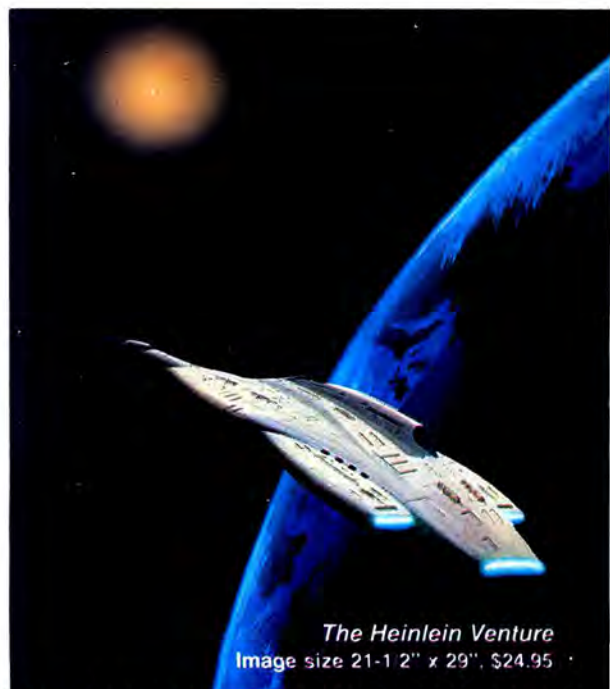
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Freedom from the microparticles that will shower it daily presents enough of a problem. The current station design calls for use of Whipple bumpers, which have been standard on manned spacecraft since the 1960s. A thin aluminum bumper plate is attached a short distance ahead of the backwall or hull of the spacecraft. Incoming particles are shattered or vaporized when they hit the bumper. What's left plops harmlessly on the backwall.

The increasing pollution of space, however, has raised concerns that a station protected only by Whipple bumpers could fall prey to a catastrophic impact. New shields are being developed at JSC—shields made of several thin layers of ceramic fiber instead of a single aluminum sheet.

Christiansen says the shielding could be upgraded even after the station is in orbit. "The idea is to go up with some amount

of protection and then add on later to make a multiple shock shield. Using flexible ceramic fabric, we might be able to just unroll this stuff up there," like adding extra insulation to an attic. Some scientists believe that up to 12 inches of multilayer bumpers will have to be added to the station during its lifetime.

But before NASA commits to the multilayer shield, abandoning a design that has proven effective for 30 years, decision makers would like more than theoretical assurances that it will work. Enter the guns of NASA's Hypervelocity Laboratory, along with similar defense department facilities at sites in Texas, New Mexico, Tennessee and Alabama.

Tests at the hypervelocity lab at JSC indicate that it's possible to design shields that are about 40 percent lighter than conventional Whipple shields, but have equal stopping power. Preliminary studies show that simply adding an aluminum mesh to a surface—rather than having it made entirely of aluminum—increases resistance to penetration, suggesting that compact rolls of mesh could be put in place over critical areas on the station.

But improved shielding will only be able to stop particles up to about two centimeters in diameter, and so far there is very little information about what happens if larger or faster particles hit the station.

The guns currently in use can fire micro-projectiles at speeds of five miles per second. NASA would like to know the effect of particles moving twice that fast, and so is planning tests using a second generation of guns called the Inhibited Shape Charge Launcher.

"With the light gas guns [such as those at JSC] we can cover about 30 percent of the expected range [of particle speeds]," says Nieder. "If we add the inhibited shape charge gun, we can cover 70 to 80 percent—debris up to 15 kilometers per second."

The new gun is scheduled for arrival at the White Sands Test Facility in New Mexico within two years. If all goes as planned, this western site will be the premier hypervelocity research center in the world. A hundred years after guns made the rules in the Old West, guns will again make the laws that will define the new frontier. And any data they can

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Even though "it's impossible to fully protect all of the pressure vessels on the space station from all meteoroid and debris impacts," says Nieder, "the consequences of such impacts need to be understood." □

Greg Freiberr's article "How to Beat the High Cost of Space" (October 1989) won the Aviation/Space Writers Association's midwest region journalism award.



"accidentally the primary mirror had been given the wrong shape"

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# SPACE CAPSULES

A record of space-related events, July-September 1990

July 16

**C**hina's powerful Long March 2E rocket, the country's latest entry in the hotly contested international launch derby, was successfully test-launched with a dummy payload onboard. The new rocket can carry 19,400 pounds of cargo into low orbit, or 9,900 pounds into a high geosynchronous orbit—a payload capacity greater than that of the Delta, Atlas and Ariane 4 vehicles now serving the satellite industry.

July 16

**N**ASA's astronaut class of 1990 reported to work at the Johnson Space Center. The 23 astronaut candidates—18 men and 5 women—include Major Eileen Collins, the first woman to be picked as a shuttle pilot, and Ellen Ochoa, the first Hispanic woman to be chosen. If they survive the training and evaluation program, the "as-cans" will become full-fledged astronauts next year.

July 24

**N**ASA announced the discovery of a previously unknown moon orbiting Saturn—the 18th and smallest one found so far. Mark Showalter, a researcher at the Ames Research Center, discovered the 12-mile-wide moonlet after using a computer to sift through some 30,000 images taken by the Voyager spacecraft in 1980 and 1981. The moon's temporary name: 1981S13.

July 24

**T**he European Ariane 4 rocket returned to flight after a five-month delay resulting from the explosion of an Ariane last February with a pair of Japanese satellites onboard. On August 30, another Ariane delivered two more satellites into orbit, putting the program firmly back on track.

July 25

**T**he Atlas 1 commercial rocket made its debut by placing the Combined Release and Radiation Effects Satellite (CRRES) into orbit for NASA and the Air Force. The spacecraft will spend a year studying interactions of the solar wind with the Earth's magnetic field. For General Dynamics, maker of the Atlas, it was the first in what the company hopes will be a long line of successes—60 Atlas vehicles are under construction, with more than 30 launch contracts in hand.

August 9

**C**osmonauts Anatoly Solovyev and Alexander Balandin returned to Earth after six months in space, during which they performed hundreds of experiments and grew high-grade crystals, which—according to Soviet claims—will net a \$20 million profit from their work onboard the Mir station. The last weeks of the mission were harrowing. Balandin and Solovyev were forced to make an unscheduled spacewalk July 18 to repair insulation that had come loose from the Soyuz module in which they were to return to Earth. A week later a second venture outside the station was required to fix a hatch bent by the crew during the first

spacewalk. On August 3, the replacement crew of Gennady Manakov and Gennady Strekalov arrived on Mir to complete repairs to the station. The two cosmonauts will remain onboard until December.

August 10

**A**fter a 15-month journey, Magellan arrived in orbit around Venus to begin mapping the planet with radar (see page 28).

September 13

**T**he Advisory Committee on the Future of the U.S. Space Program, created by Vice President Quayle and the National Space Council during one of NASA's worst summers ever, held its first public meeting in Washington. The group's charter is to recommend how NASA and other government agencies can best be organized to carry out the ambitious space programs envisioned for the next century. Norman Augustine, the Martin Marietta chairman who heads the panel of mostly aerospace industry veterans, vowed that his group will take a fresh look at all the issues facing the U.S. space program. "We'll do what we think is right," said Augustine, "and let the chips fall where they may." The panel's report is due by the end of the year.

## Upcoming Events

December 8

Galileo flies within 600 miles of Earth for a gravity assist that will speed the spacecraft on its voyage to Jupiter.

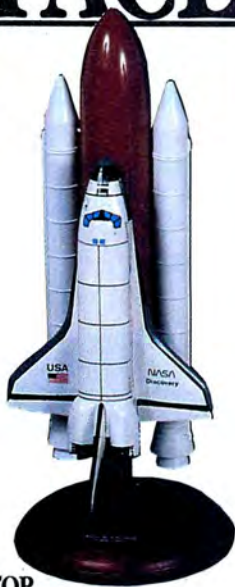
**August 9: Columbia (left) and Atlantis pass in the night—one bound for the launchpad, another back for repairs.**



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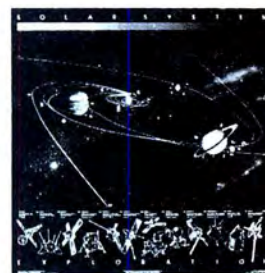
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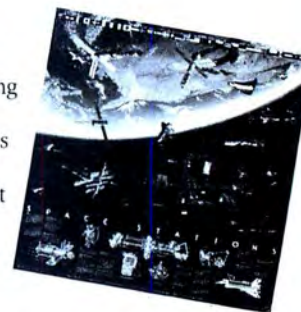
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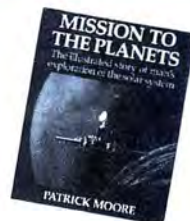
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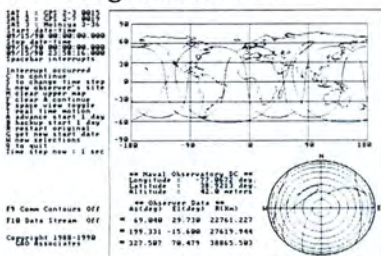
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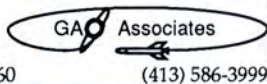
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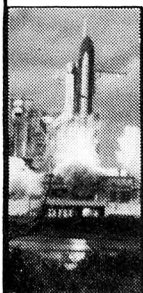


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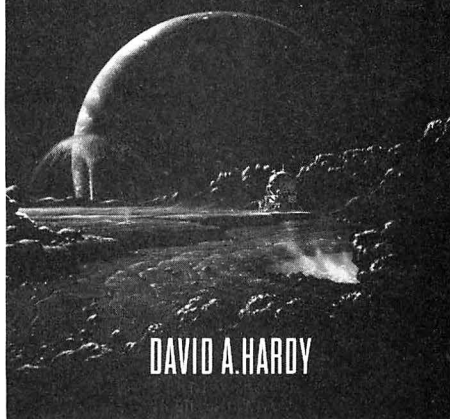
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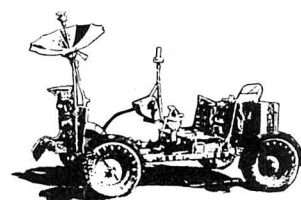
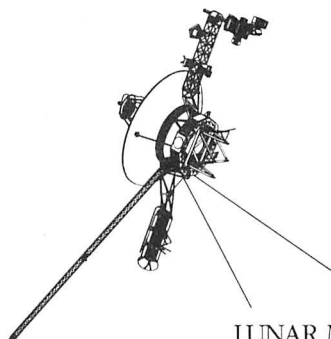
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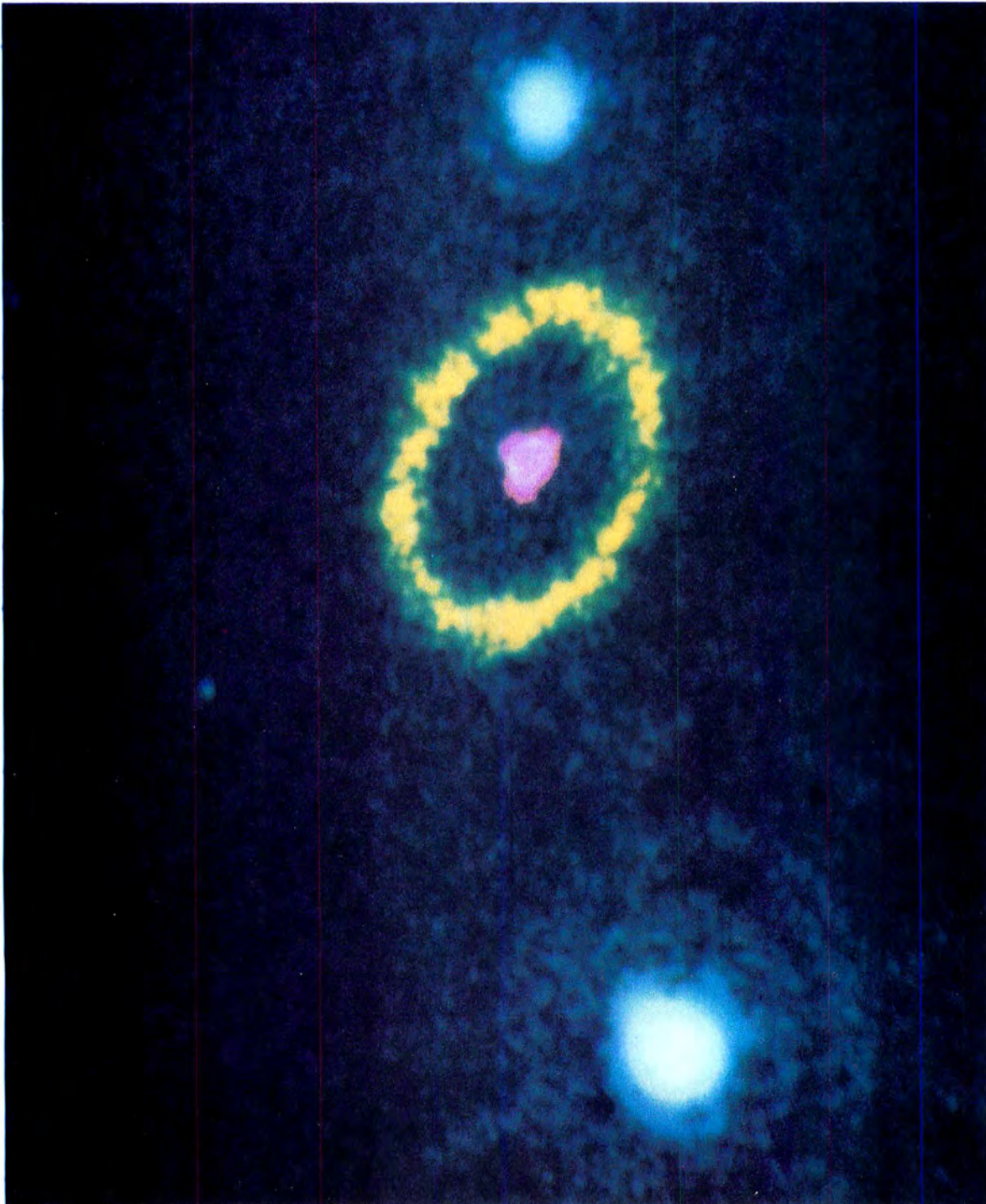
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# Destinations

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*Rudyard Kipling*



Hubble Space Telescope photo showing new detail in an expanding ring of gas surrounding the remains of Supernova 1987A.



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